Summary Highlights of NRC/DOE Technical Exchange on DOE's Pre-Closure Safety Analysis Guide

April 25-26, 2002
Rockville, Maryland

Introduction and Objectives

This Technical Exchange to discuss Pre-Closure Safety is one in a series of meetings related to the U.S. Nuclear Regulatory Commission (NRC) and U.S. Department of Energy (DOE) issue resolution process. Consistent with NRC regulations on prelicensing interactions and a 1992 agreement with the DOE, staff-level resolution can be achieved during prelicensing interaction. The purpose of issue resolution is to assure that sufficient information is available on an issue to enable the NRC to docket a proposed license application. Resolution at the staff level does not preclude an issue being raised and considered during the licensing proceedings, nor does it prejudge what the NRC staff evaluation of that issue will be after its licensing review. Issue resolution at the staff level, during prelicensing, is achieved when the staff has no further questions or comments at a point in time regarding how the DOE is addressing an issue. Additional information (e.g., changes in design parameters) could raise new questions or comments regarding a previously resolved issue.

Issues are "closed" if the DOE approach and available information acceptably address staff questions such that no information beyond what is currently available will likely be required for regulatory decision making at the time of any initial license application. Issues are "closed-pending" if the NRC staff has confidence that the DOE proposed approach, together with the DOE agreement to provide the NRC with additional information (through specified testing, analysis, etc.) acceptably addresses the NRC's questions such that no information beyond that provided, or agreed to, will likely be required at the time of initial license application. Issues are "open" if the NRC has identified questions regarding the DOE approach or information, and the DOE has not yet acceptably addressed the questions or agreed to provide the necessary additional information in a potential license application.

By letter dated March 27, 2002, DOE submitted information pertaining to two NRC/DOE agreements. In response to Pre-Closure Agreement 6.01, a procedure entitled "Classification Criteria and Maintenance of the Monitored Geologic Repository Q-List" was provided. In that same letter, DOE provided its Pre-Closure Safety Analysis Guide in response to Pre-Closure Agreement 6.02. The objective of this meeting was for DOE to present an overview of the Pre-Closure Safety Analysis Guide and to discuss the NRC's initial comments on the document.

No new agreements were reached at this meeting. The agenda and the attendance list are provided as Attachments 1 and 2, respectively. Copies of the presenters' slides and the NRC's preliminary comments are provided as Attachment 3. Highlights from the Technical Exchange are discussed below.

Summary of Meeting

1) Overview of Meeting

NRC provided some general background for this topic. NRC stated that during a Technical Exchange and Management Meeting held on July 24-26, 2001, NRC and DOE discussed several pre-closure topics and reached several pre-closure agreements as a result of those discussions. As previously mentioned, DOE submitted two documents in response to Pre-Closure Agreements 6.01 and 6.02 on March 27, 2002. NRC has performed an initial review of the documents and provided its preliminary comments to DOE in preparation for this meeting. The comments are provided in the NRC handout (see Attachment 3) and were discussed during the meeting. NRC stated that it plans to complete its review of the documents in June 2002, and provide DOE with the result of that review. At that time, the NRC stated it would discuss whether the information provided in the March 27, 2002, letter and discussion during this meeting satisfies the intent of the agreement.

2) Overview of Pre-Closure Safety Analysis Guide

DOE provided an introduction to the meeting (Attachment 3) and stated that the objective of the meeting is to provide an overview of the Pre-Closure Safety Analysis Guide. DOE stated that the Pre-Closure Safety Analysis Guide is not a document subject to the DOE Quality Assurance Requirements Document controls and that it is not the procedure controlling the Q-List or the quality level classification of systems, structures, and components on the Q-List. Further, DOE stated that products which use the Pre-Closure Safety Analysis Guide methodologies will be developed and controlled in accordance with the Quality Assurance Requirements Document and will be self-contained. NRC stated that DOE needed to have procedures in place, with sufficient detail, so that qualified individuals can perform Q-List and quality level classification activities in a consistent manner. DOE stated that its intent was to have procedures in place, as required by 10 CFR Part 63 [specifically 63.142(f)]. Further, DOE stated that the documents referred to in these procedures that prescribe how to perform related activities such as calculations, analyses, independent verifications, reviews and approvals, etc., would also be subject to the Quality Assurance Requirements Document controls.

DOE stated that it may update the Pre-Closure Safety Analysis Guide based on its review of the Yucca Mountain Review Plan, interactions with other organizations, and other feedback processes. DOE stated that the intent of the Guide is to assist with the preparation of the Pre-Closure Safety Analysis and to serve as a training tool for the technical staff. DOE also stated that although the current version focuses on offsite dose, subsequent revisions will address the interfaces with worker dose analyses. NRC and DOE then discussed, in general, the information included in each of the Pre-Closure Safety Analysis Guide sections. DOE stated that, as a path forward, it intends to develop additional sections and provide additional detail on certain topics. NRC and DOE discussed the need to integrate the Pre-Closure Safety Analysis with design and present this information in the Pre-Closure Safety Analysis Guide. DOE stated that it plans to consider feedback (e.g., from the NRC) and incorporate it in subsequent revisions, as appropriate.

3) Discussion of Pre-Closure Safety Analysis Guide Sections

NRC and DOE then discussed specific sections of the Pre-Closure Safety Analysis Guide; the sections discussed are listed below.

Section 3: Strategy

DOE discussed its key pre-closure safety strategies and stated that its construction application project guideline goal is to design the facility to keep the dose limits to less than or equal to one-half of the applicable regulatory limits. NRC and DOE discussed margins and defense-in-depth and DOE stated it intends to design structures, systems, and components with a margin above what is credited for in the Pre-Closure Safety Analysis. At a later presentation, DOE indicated that the project guideline goal is intended for early stage of the pre-closure safety strategies. At the license application for construction authorization, DOE intends to demonstrate compliance with regulatory limits. NRC noted that the issue of margins and defense-in-depth will be very important in implementing 10 CFR 63.44 for changes, tests, and experiments. DOE also stated that it would use, as appropriate, nuclear industry precedent and experience. DOE noted that Section 3 provides preferred approaches, in general, such as passive over active and automatic over manual systems. Finally, NRC and DOE discussed example pre-closure safety strategies.

Section 4: Overview of Pre-Closure Safety Analysis Elements and Approaches

DOE provided an overview of the process it will use for the Pre-Closure Safety Analysis. NRC and DOE discussed the level of design detail and information base for the potential license application for construction authorization. In summary, DOE stated that the design detail will be sufficient to show that it meets the requirements of 10 CFR Part 63 as discussed during the last Technical Exchange (July 2001) where the staff provided a paper describing acceptable levels of design details. DOE stated that at the time of the license application for construction authorization, the Pre-Closure Safety Analysis will support the demonstration that the geologic operations area has been designed to preserve the option of waste retrieval. DOE also stated that if retrieval becomes necessary, DOE will submit safety analyses on retrieval design and operation for NRC review.

Section 6: Hazard Analysis

DOE presented an overview of the external hazards analysis process. NRC and DOE discussed the process DOE used to develop the generic hazards list and the method used to screen out external hazards not applicable to the proposed repository and some examples of how that process was implemented. DOE then presented an overview of the internal hazards analysis process. NRC and DOE discussed the six DOE categories for internal hazard analysis: (1) collision/crushing, (2) chemical contamination/flooding, (3) explosion/implosion, (4) fire, (5) radiation/magnetic/electrical/fissile, and (6) thermal. NRC and DOE then discussed several DOE examples of how the internal hazard analysis process was implemented. DOE and NRC discussed the need to consider three factors - radionuclide release, criticality, and reduction of shielding - in hazard identification analyses. As a result of the hazard analysis process, DOE then would develop an internal hazards event list that must be evaluated. The external and internal hazards analysis will be the basis for identifying initiating events.

Section 10.1: External - Seismic

DOE presented its approach to include seismic effects into the Pre-Closure Safety Analysis and stated that its approach is consistent with DOE's Seismic Topical Report No. 2. DOE also stated that it uses the guidance provided in the Yucca Mountain Review Plan, Commission Papers, NRC publications (i.e., NUREGs), and the requirements of 10 CFR Part 63. NRC and DOE then discussed, in more detail, several aspects of the seismic analysis for the Pre-Closure Safety Analysis and a hypothetical example of a baseline seismic event tree. NRC and DOE discussed the need to have a separate interaction regarding DOE's seismic design/fragility analyses, both for pre-closure and post-closure. As a point of clarification, DOE indicated that the design basis earthquakes for structures, systems, and components related to criticality and waste package retrieval would be determined in a manner consistent with the seismic consideration of other structures, systems, and components.

Section 7: Event Sequences

DOE discussed the methodologies used for construction and development of event tree and fault tree analysis and provided some references it is using to implement the methodology. NRC and DOE then discussed human reliability analysis and DOE stated that its approach is based on methods developed by NRC and the Electric Power Research Institute that have been applied in prior probabilistic risk assessments and individual plant examination studies. NRC and DOE discussed the DOE approach for identifying common-cause and dependent failures and DOE stated that it was using the beta-factor approach. NRC and DOE discussed how DOE plans to gather and quantify technical information that is used in the quantification of fault trees and event trees. Finally, NRC and DOE discussed how DOE defines the bases and methods for applying the results of the event tree sequence quantification to categorize credible event sequences according to the definitions of 10 CFR 63.2. DOE proposed to consider event sequences down to a frequency of 10^{-8} per year. Structure, systems, and components that mitigate or prevent event sequences may be included in the Q-List.

Section 8: Consequences

DOE discussed the methodology for calculating offsite doses for Category 1 and Category 2 event sequences. NRC and DOE discussed source terms, specifically for commercial spent nuclear fuel, crud, DOE spent nuclear fuel, vitrified high-level radioactive waste, mixed plutonium and uranium waste forms, and Navy spent fuel. DOE noted that references to the source term for Navy spent fuel, co-disposal plutonium, and MOX fuel were not discussed in the Pre-Closure Safety Analysis Guide, but will be included in future revisions, as appropriate. NRC and DOE discussed methodologies for Category 1 and 2 event sequence offsite dose calculations, Category 1 and 2 dose pathways, and commercial spent nuclear fuel release fractions. NRC noted its position that DOE should demonstrate the facility design is in compliance with the performance objectives for all pathways without the need for interdiction. DOE responded it would consider the NRC position for including the ingestion pathway in the consequence analyses for Category 2 event sequences. NRC noted the general need for the Pre-Closure Safety Analysis Guide to better address and integrate analyses for onsite workers. DOE agreed future updates to the Pre-Closure Safety Analysis Guide would address the interfaces with onsite worker dose analyses.

Section 9: Uncertainty Analysis

DOE discussed how the uncertainty/sensitivity analyses will be applied in the Pre-Closure Safety Analysis. DOE stated that Section 9 provides the methods for identifying, quantifying, propagating, and interpreting uncertainties in frequency and consequence analyses. DOE noted that other sections of the Pre-Closure Safety Analysis Guide also address facets of uncertainty analysis, and its application. NRC and DOE discussed the different types of uncertainty and how the uncertainty would be identified, treated, and propagated through the event sequence frequency and consequence analyses. Finally, NRC and DOE discussed how sensitivity studies could be used to give risk insights to specific events.

Section 13: 10 CFR 63.2 Design Basis

DOE discussed the definition of design bases and the relationship of 10 CFR 63.2 design bases to the licensing bases. DOE emphasized that analyses are based on the functions applicable to each event sequence. DOE stated that pre-closure design basis requirements will be developed from the geologic repository Category 1 and 2 event sequences identified in the Pre-Closure Safety Analysis. NRC and DOE discussed the DOE process for developing the final set of bounding 10 CFR 63.2 design bases. DOE also provided two specific examples and discussed the functional design bases, controlling parameter design bases, and supporting design information.

Section 12: Classification Process - AP-2.22Q

DOE discussed the classification methodology provided in the Pre-Closure Safety Analysis Guide and briefly discussed Procedure AP-2.22Q, "Classification Criteria and Maintenance of the Monitored Geologic Repository Q-List" and its classification process. NRC and DOE discussed the adequacy of the guidelines provided in AP-2.22Q. NRC and DOE discussed the important to safety classification criteria and the specific quality levels. NRC and DOE discussed the important to safety classification steps for classifying structures, systems, and components in Category 1 and 2 event sequences. NRC and DOE then discussed three hypothetical examples of how the classification process would be implemented. DOE stated that it would make the Q-List consistent with the classification analyses and provided an example Q-List. In addition, DOE stated that it would be periodically providing the staff with updated Q-List. As a path forward, DOE stated that it plans to include in future Pre-Closure Safety Analysis Guide revisions: (1) classification of structures, systems, and components related to criticality, (2) classification of structures, systems, and components related to radiological worker safety for Category 1 event sequences, and (3) Q-List format and maintenance. NRC commented that the Pre-Closure Safety Analyses for worker consideration and important to waste isolation designations arising from the post-closure total system performance assessment contributions to the Q-List and structures, systems, and component categorizations should be included. NRC noted that terminology related to categorization were not consistent throughout the Pre-Closure Safety Analysis Guide. DOE stated that the next revision will introduce consistent terminology.

4) Yucca Mountain Review Plan - Pre-Closure Safety Analysis Guide Comparison

DOE discussed its ongoing comparison between the draft Yucca Mountain Review Plan and the Pre-Closure Safety Analysis Guide. DOE stated that the Pre-Closure Safety Analysis Guide appears consistent with corresponding sections of the draft Yucca Mountain Review Plan, with some of the exceptions noted during the meeting. DOE stated that future revisions would be linked to the Yucca Mountain Review Plan, as appropriate, and would develop details and/or new methods sections for areas not completed in the current version (e.g., internal event floods and fires, vulnerabilities to software unreliability, and work interfaces and responsibilities). DOE also noted that it intends to develop a license application that is consistent with the format and content of the Yucca Mountain Review Plan.

5) Public Comments

None

For
Janet Schlueter
Chief, High Level Waste Branch
Division of Waste Management
Office of Nuclear Material Safety
and Safeguards
Nuclear Regulatory Commission

for Claudia M. Newbury
Acting Team Lead
Regulatory Interactions and Policy Development
Office of Licensing & Regulatory Compliance
Department of Energy

Attachment 1

Meeting Agenda

AGENDA
PRECLOSURE SAFETY ANALYSIS TECHNICAL EXCHANGE
April 25-26, 2002
Rockville, Maryland

April 25, 2002

08:00 – 08:15 AM	**Introduction and Opening Remarks (purpose of guide, schedule, outline, consistent with 10 CFR 63, YMRP) - DOE**
08:15 – 08:30 AM	**Overview of Meeting - NRC**
08:30 – 10:00 AM	**Preclosure Safety Analysis Guide Overview - DOE**
10:00 – 10:15 AM	**Break**
10:15 – 10:45 AM	**Section 3 – Strategy (key preclosure safety strategies, example application) – DOE**
	Section 4 – Overview of PSA Elements and Approaches (demonstration that PSA approach is consistent with design development) - DOE
10:45 – 12:00 PM	**Section 6 – Hazards Analysis (overview, external hazards process, examples, internal hazards process, examples) - DOE**
12:00 –1:00 PM	**Lunch**
1:00 – 2:15 PM	**Section 10.1 External – Seismic (overview, process, examples) - DOE**
2:15 – 3:30 PM	**Section 7 – Event Sequences (overview, process, examples) - DOE**
3:30 –3:45 PM	**Break**
3:45 – 4:30 PM	**DOE/NRC Caucus**
4:30 – 5:00 PM	**Day 1 Summary**
5:00 PM	**Adjourn Day One**

Attachment 2

Attendance List

Attendees
NRC-DOE Technical Exchange on Preclosure Safety Analysis Guide

April 25, ~~02~~ 2002
April 26, 2002

Name	Organization	Phone#	E-mail
DENNIS RICHARDSON	BSC	702-295-3137	DENNIS_RICHARDSON@YMP.GOV
PAUL HARRINGTON	DOE/YMSCO	702-794-5415	paul_harrington@ymp.gov
JACK BESS	BSC	702-295-4032	Jack_Bess@ymp.gov
Dealis Gwyn	BSC	702-295-3964	Dealis_Gwyn@ymp.gov
TOM DUNN	BSC	702-295-5993	Thomas_Dunn@ymp.gov
Jim Follin	NR/Bettis	412 476 5934	follinjn@bettis.gov
Douglas ORVIS	BSC	702 295 4137	Douglas_Orvis@NOTES.YMP.GOV
Asadul H. Chowdhury	CNWRA	210 522-5151	achowdhury@swri.edu
DON BECKMAN	BSC/YMP	702-295 4358	DONALD_BECKMAN@NOTES.YMP.GOV
BISWAJIT DASGUPTA	CNWRA	210-522-6815	bdasgupta@swri.edu
Simon Hsiung	CNWRA	210-522-5209	shsiung@swri.org
Amitava Ghosh	CNWRA	210-522-3314	aghosh@swri.org
Roland Benke	CNWRA	210-522-5250	rbenke@swri.org
Doug Gute	CNWRA	210-522-2307	dgute@swri.org
Norman Eisenberg	CNWRA/CONSULTANT	301-384-6507	naeisenberg@earthlink.net
Baky Ibrahim	NRC	301-415 6651	aki@nrc.gov
Banad Jagannath	NRC	301-4156653	BNJ@NRC.GOV
Bob Bradbury	MTS/SAIC	702 794 5424	robert_bradbury@ymp.gov
GUY MARTIN	BSC	702 295-4224	GUY_MARTIN@NOTES.YMP.GOV
George Hellstrom	DOE/CCO	702-794-1419	hellstromg@YMP.gov
STAN ECHOLS	ECG	202-537-1468	echolsconsulting@earthlink.net
ROBERT K. JOHNSON	NRC/NMSS	301.415.6900	RKJ
LARRY L. CAMPBELL	NRC/NMSS	301 415-5000	llc3@nrc.gov
Leon Reiter	NWTRB	703 235-4490	reiter@nwtrb.gov
Steve Frishman	NV NWPO	775-687-3744	ssteve@nuc.state.nv.us
DANIEL ROM	NRC/NMSS	301-415-6704	DSR@NRC.GOV

Attendees
NRC-DOE Technical Exchange on Preclosure Safety Analysis Guide

April 25, ~~02~~ 2002
April 26, 2002

Name	Organization	Phone#	E-mail
Latif Hamdan	ACNW/NRC	301 415 6639	LSH@NRC.GOV
Tae Ahn	NMSS/NRC	301 415-5812	tma@nrc.gov
WILKINS SMITH	NRC/NMSS/FCSS	301-415-5788	WRS@NRC.GOV
James Andersen	NMSS/NRC	301-415-5717	jwa@nrc.gov
Mysore Nataraja	NMSS/NRC	301-415-6655	msn1@nrc.gov
David Dancer	NMSS/NRC	301-415-6618	dmd@nrc.gov
Tim Sweeney	BSC	202-479-2107	Timothy_Sweeney@ymp.gov
RON LLOYD	NRC	301-415-7479	RLL1@NRC.GOV
N Breland	NRC/OGC	301 415 2490	NRB
TIM GUNTER	DOE/YMSCO	702-794-1343	timothy_gunter@ymp.gov
Tammy Bloomer	NMSS	301 415 6626	TEB@NRC.GOV
LARRY Campbell	NMSS/HLWB	301 415-5000	llc3@nrc.gov
Mike Markley	NMSS/HLWB	301-415-6885	mtm@nrc.gov
Tae Ahn	NMSS/HLWB	301-415-5812	tma@nrc.gov
Tim McCartin	NMSS/NRC	301 415 7285	tjm3@nrc.gov
Nick D.Nunzio	DOE	202 586 8953	Nick.DiNunzio@RW.DOE.Gov

CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES
MEETING ATTENDANCE

SUBJECT OF MEETING PRECLOSURE SAFETY ANALYSIS TECHNICAL EXCHANGE

DATE: 4/25/2002 AND 4/26/2002 LOCATION: CNWRA, BLDG 189, Rm A-132

PERSON	ORGANIZATION	TITLE/FUNCTION	TELEPHONE NUMBER
Wesley Patrick	CNWRA	PRESIDENT	210-522-5158
Oleg Povetko	CNWRA	RES. ENG.	210-522-5258
Goodluck Ofoegbu	CNWRA	Principal Engr.	210-522-6641
Troy Maxwell	CNWRA	Engineer	210-522-2012
John Stamatakos	CNWRA	Principal Res Sci	210 522 5247
Budhi Sagar	〃	Tech Dir.	X5252

Post-it™ Fax Note 7671	Date	# of pages ▶
To James Anderson	From Wes Patrick	
Co./Dept. NRC	Co. CNWRA	
Phone #	Phone # 210-522-5158	
Fax # 301-415-5398	Fax #	

CNWRA Form AP-5

Attachment 3

Meeting Handouts

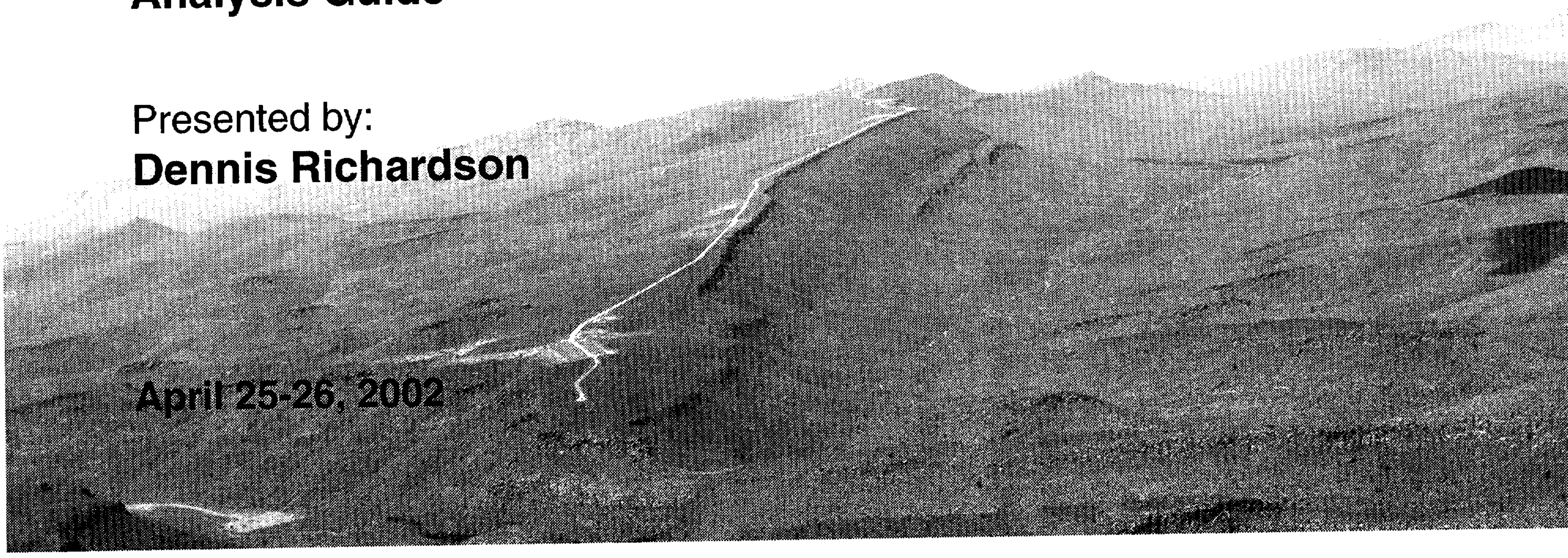
U.S. Department of Energy
Office of Civilian Radioactive Waste Management

YUCCA MOUNTAIN PROJECT

Preclosure Safety Analysis Guide - Introduction

Presented to:
NRC Technical Exchange on Preclosure Safety Analysis Guide

Presented by:
Dennis Richardson



April 25-26, 2002

Agenda

- **Meeting Objective**
- **Preclosure Safety Analysis Guide Purpose**
- **Updates**
- **Summary**

Objective

- Provide an overview of the Preclosure Safety Analysis Guide
- More focus on selected sections
- Facilitate detailed interactions in future on specific topics

Preclosure Safety Analysis Guide Purpose

- **Provide guidance to Preclosure Safety Analysis Team on methods to meet regulatory requirements**
  - **Preferred, not required methods**
  - **Uniformity in analyses and databases**
  - **Basis for training**
  - **Improved communications**
  - **Products that use methods will be developed under Quality Assurance program**
    - **Includes discussion, check, and approval of methodology used to perform calculation**

Updates

- Yucca Mountain Review Plan
- Preclosure Safety Analysis
  - Feedback
  - Development
- Interactions
  - Yucca Mountain Project
  - Nuclear Regulatory Commission
  - Other
- Annual updates planned

Summary

- Two day meeting will provide an overview of the Preclosure Safety Analysis Guide
- Guide is a tool for developing Preclosure Safety Analysis
- Planned updates to the Guide

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

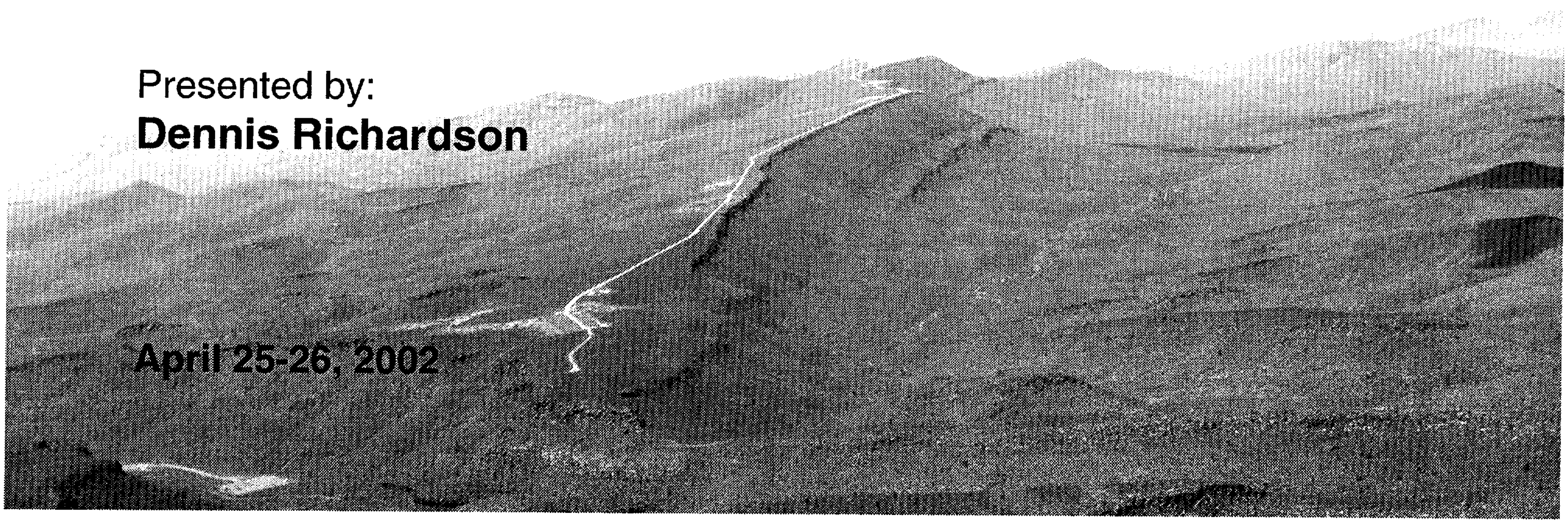
YUCCA MOUNTAIN PROJECT

Preclosure Safety Analysis Guide - Overview of Preclosure Safety Analysis

Presented to:
NRC Technical Exchange on Preclosure Safety Analysis Guide

Presented by:
Dennis Richardson

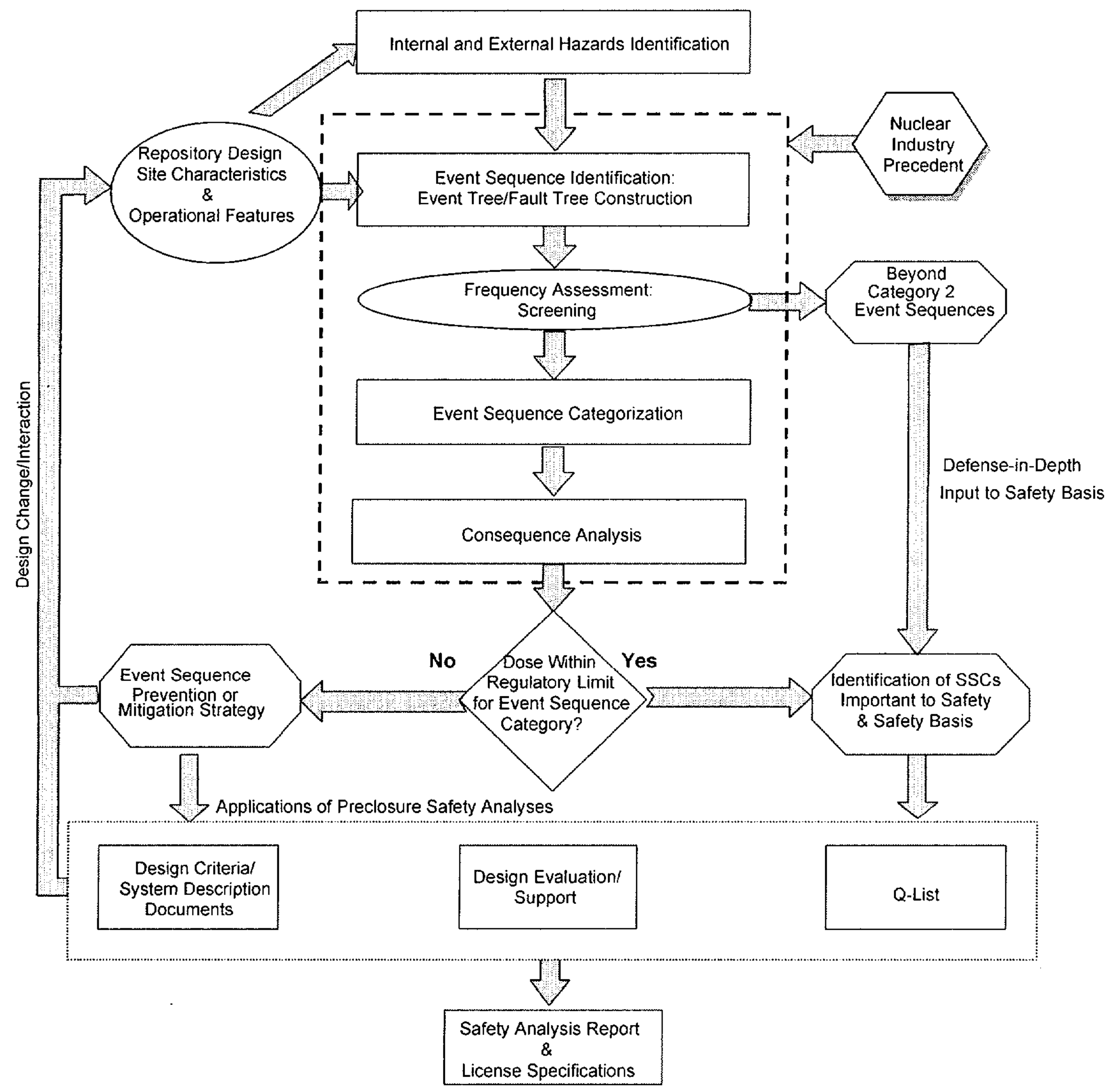
April 25-26, 2002



Agenda

- **Overview**
- **Preclosure Safety Analysis Process**
- **Summary**

Overview



Internal and External Hazards Identification
Nuclear Industry Precedent
Repository Design Site Characteristics & Operational Features
Event Sequence Identification: Event Tree/Fault Tree Construction
Frequency Assessment: Screening
Beyond Category 2 Event Sequences
Event Sequence Categorization
Defense-in-Depth Input to Safety Basis
Consequence Analysis
Design Change/Interaction
No
Yes
Dose Within Regulatory Limit for Event Sequence Category?
Event Sequence Prevention or Mitigation Strategy
Identification of SSCs Important to Safety & Safety Basis
Applications of Preclosure Safety Analyses
Design Criteria/ System Description Documents
Design Evaluation/ Support
Q-List
Safety Analysis Report & License Specifications

Developing and Documenting the PSA

- **Level of Design Detail for LA-CA**
- **Information Base for PSA-LA**
- **Preclosure Safety Analysis for LA-CA**
- **Demonstrating Compliance with 10 CFR 63.112(e)**

Developing and Documenting the PSA
(Continued)

- **Level of Design Detail in LA-CA**
  - Sufficient assurance that preclosure performance objectives will be met by final design
  - Preclosure safety design bases
  - Description of SSCs that are required to protect health and safety of public and workers
    - Category 1 and 2 event sequences, as appropriate
    - Demonstrate compliance with preclosure performance objectives
  - Identify SSCs important to safety

Developing and Documenting the PSA
(Continued)

- **Information Base for LA-CA**
  - Regulatory requirements
  - Site information
  - Industry codes and standards
  - Regulatory and industry precedents
  - Good practices in similar operations
  - PSA team experience and knowledge
  - Design concepts and principles of construction and operation

Developing and Documenting the PSA
(Continued)

- Characterization of waste forms
- Waste receipt rate
- Concurrent construction plan
- Subsurface
  - Layout
  - Ground control
  - Ventilation
  - Fire protection
  - Waste package transport and emplacement concepts
  - Rescue, recovery, and decontamination of disabled transport and emplacement equipment

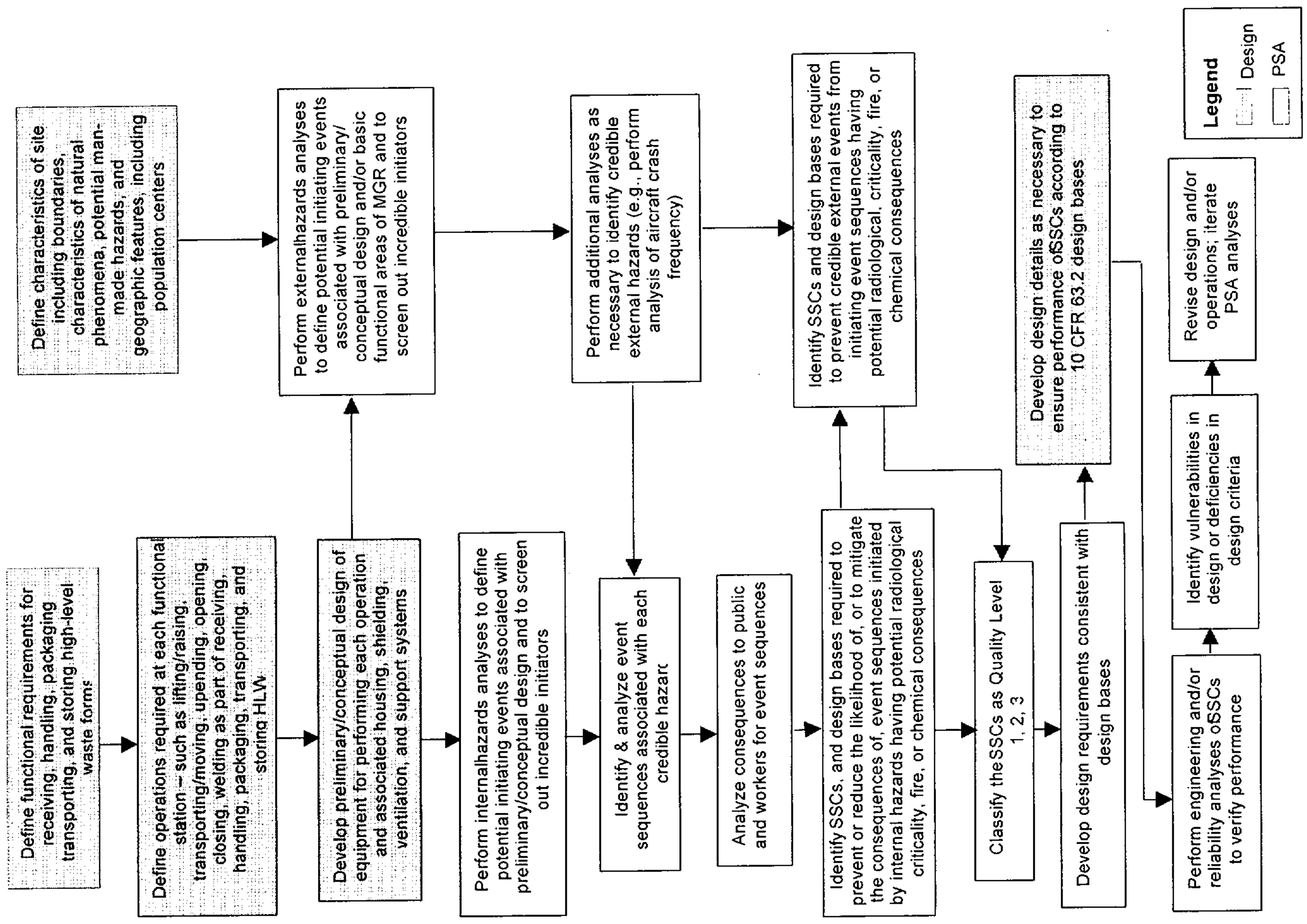
Developing and Documenting the PSA
(Continued)

- Waste package
  - Design bases
  - Criticality control features
  - Sealing
  - Remediation
  - Source terms

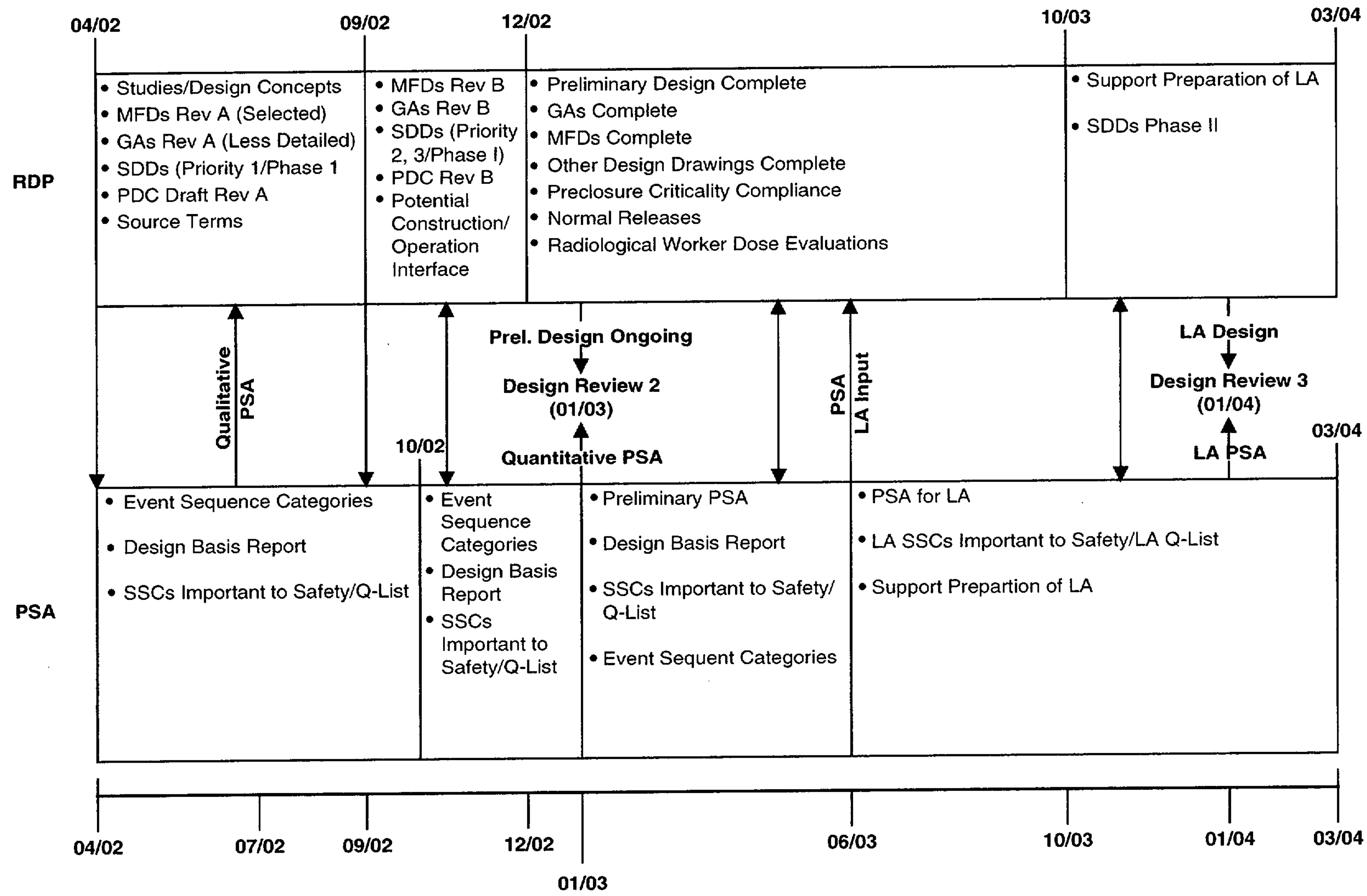
Developing and Documenting the PSA
(Continued)

- Surface
  - Layout
  - Functional descriptions of operations
    - Receiving
    - Handling
    - Packaging
    - Staging
    - Transporting
  - Throughput rate
  - Construction concepts
  - Preclosure safety design bases and requirements

PSA for LA


Define characteristics of site including boundaries, characteristics of natural phenomena, potential man-made hazards, and geographic features, including population centers
Perform externalhazards analyses to define potential initiating events associated with preliminary/ conceptual design and/or basic functional areas of MGR and to screen out incredible initiators
Perform additional analyses as necessary to identify credible external hazards (e.g., perform analysis of aircraft crash frequency)
Identify SSCs and design bases required to prevent credible external events from initiating event sequences having potential radiological, criticality, fire, or chemical consequences
Develop design details as necessary to ensure performance ofSSCs according to 10 CFR 63.2 design bases
Legend
Design
PSA
Define functional requirements for receiving, handling, packaging transporting, and storing high-level waste forms
Define operations required at each functional station – such as lifting/raising, transporting/moving, upending, opening, closing, welding as part of receiving, handling, packaging, transporting, and storing HLW
Develop preliminary/conceptual design of equipment for performing each operation and associated housing, shielding, ventilation, and support systems
Perform internalhazards analyses to define potential initiating events associated with preliminary/conceptual design and to screen out incredible initiators
Identify & analyze event sequences associated with each credible hazard
Analyze consequences to public and workers for event sequences
Identify SSCs, and design bases required to prevent or reduce the likelihood of, or to mitigate the consequences of, event sequences initiated by internal hazards having potential radiological criticality, fire, or chemical consequences
Classify the SSCs as Quality Level 1, 2, 3
Develop design requirements consistent with design bases
Perform engineering and/or reliability analyses ofSSCs to verify performance
Identify vulnerabilities in design or deficiencies in design criteria
Revise design and/or operations; iterate PSA analyses

RDP/Preclosure Safety Analysis Interface for LA



ACRONYMS:
GA: General Arrangement Drawing; LA: License Application; MFD: Mechanical Flow Diagram;PDC: Project Design Criteria; PSA: Preclosure Safety Analysis; RDP: Repository Design Project; SDD: System Description Document; SSC: Structures, Systems, and Components

Ensuring Performance of Important to Safety SSCs

Item	10 CFR 63.112(e) Requirement	Potential Approach for LA-CA
(1)	Means to limit concentration of radioactive material in air;	Radiation Protection Program strategy; Radiation confinement areas; Design criteria/bases for HVAC
(2)	Means to limit the time required to perform work in the vicinity of radioactive materials;	Radiation Protection Program strategy; Use of remote handling and maintenance equipment
(3)	Suitable shielding;	Radiation Protection Program strategy; Design bases for shielding; Preliminary shielding analysis of principal operations areas
(4)	Means to monitor and control the dispersal of radioactive contamination;	Radiation Protection Program strategy; Radiation confinement areas; Design bases for HVAC; Design criteria for Radiation Monitoring System
(5)	Means to control access to high radiation areas or airborne radioactivity area;	Radiation Protection Program strategy; Radiation confinement areas; Design bases for Radiation Monitoring System ; Design bases for interlocks and administrative controls
(6)	Means to prevent and control criticality;	Criticality safety strategy; Design bases for criticality controls of operational areas and waste packages
(7)	Radiation alarm system to warn of significant increases of radiation levels, concentrations of radioactive material in air, and increased radioactivity in effluents;	Radiation Protection Program strategy; Design bases for Radiation Monitoring System; Preliminary analyses of performance of Radiation Monitoring System
(8)	Ability of structures, systems, and components to perform their intended safety functions, assuming the occurrence of event sequences;	Design bases for SSCs including performance requirements derived from hazards and event sequence analyses, operating environments, and ability to withstand natural phenomena
(9)	Explosion and fire detection systems and appropriate suppression systems;	Fire Protection strategy; Preliminary fire hazards analyses
(10)	Means to control radioactive waste and radioactive effluents, and permit prompt termination of operations and evacuation of personnel during an emergency;	Radiation Protection Program strategy; Design bases for waste treatment building and systems; Design bases for Radiation Monitoring System including alarms; Preliminary emergency plans
(11)	Means to provide reliable and timely emergency power to instruments, utility service systems, and operating systems important to safety if there is a loss of primary electric power;	Design bases for primary and backup power sources for SSCs important to safety as appropriate to their safety function and need for continuing power or other support (e.g., radiation monitoring and continuation of cooling or air circulation) on loss of primary power source
(12)	Means to provide redundant systems necessary to maintain, with adequate capacity, the ability of utility services important to safety; and	Design bases for primary and redundant subsystems and power sources for SSCs important to safety as appropriate to their safety function and reliability requirements (e.g., to ensure sufficient small likelihood of an event sequence, or to ensure availability of mitigation function); Process flow, piping and instrumentation diagrams, and electrical one-line diagrams, as appropriate, to demonstrate the capability
(13)	Means to inspect, test, and maintain structures, systems, and components important to safety, as necessary, to ensure their continued functioning and readiness.	Design requirements to ensure that inspections, tests, and maintenance can be carried out; Preliminary commitments to administrative controls (e.g., preliminary licensing specifications) for carrying out periodic surveillance and tests to ensure availability of SSCs important to safety

Summary

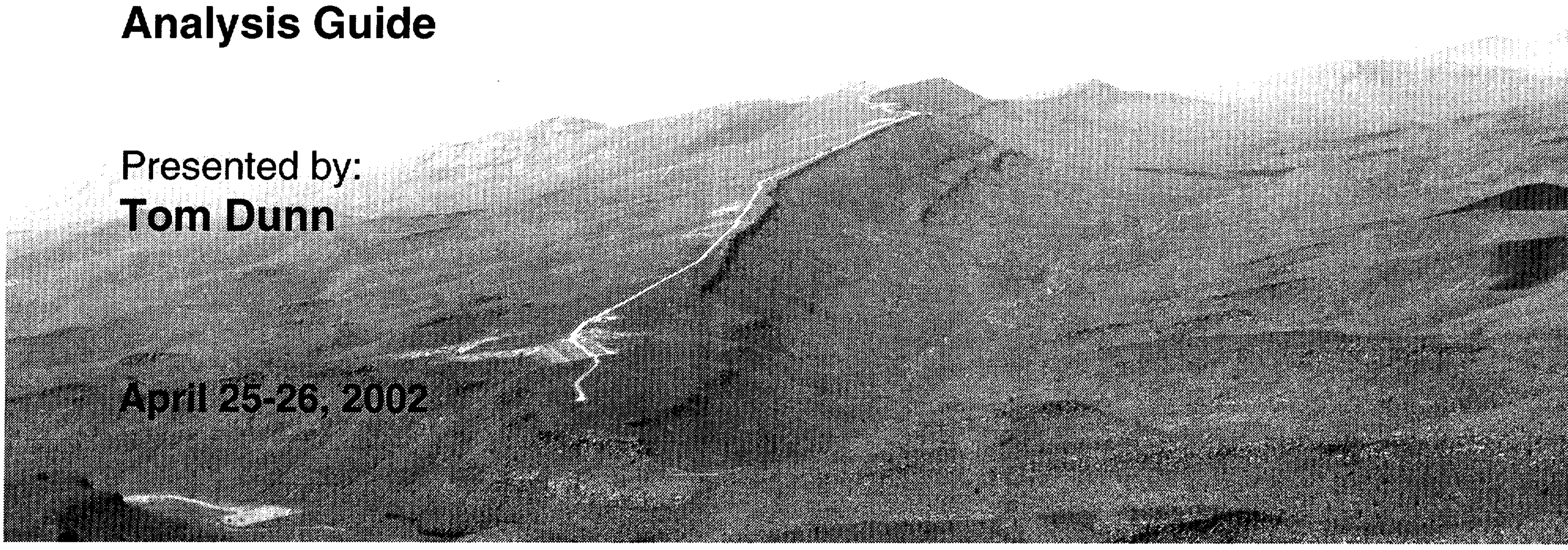
- **Design detail will be sufficient**
  - Development of preclosure safety analysis that meets requirements of 10 CFR 63
  - Preclosure safety 10 CFR 63.2 design bases
  - Reasonable assurance that no adverse radiological impacts on public and workers

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

YUCCA MOUNTAIN PROJECT

Preclosure Safety Analysis Guide - Preclosure Safety Strategy

Presented to:
NRC Technical Exchange on Preclosure Safety Analysis Guide



Presented by:
Tom Dunn

April 25-26, 2002

Agenda

- Preclosure Safety Case
- Strategies
- Example Applications
- Summary

Preclosure Safety Case

- **Preclosure Safety Analysis**
  - Demonstrate compliance with preclosure performance objectives
- **Margin and Defense-in-Depth**
  - Margin - difference between calculated event sequence consequences and regulatory compliance limits
    - Analysis uncertainties, operational flexibility, and additional safety confidence
    - Construction application guidelines - one half regulatory limits

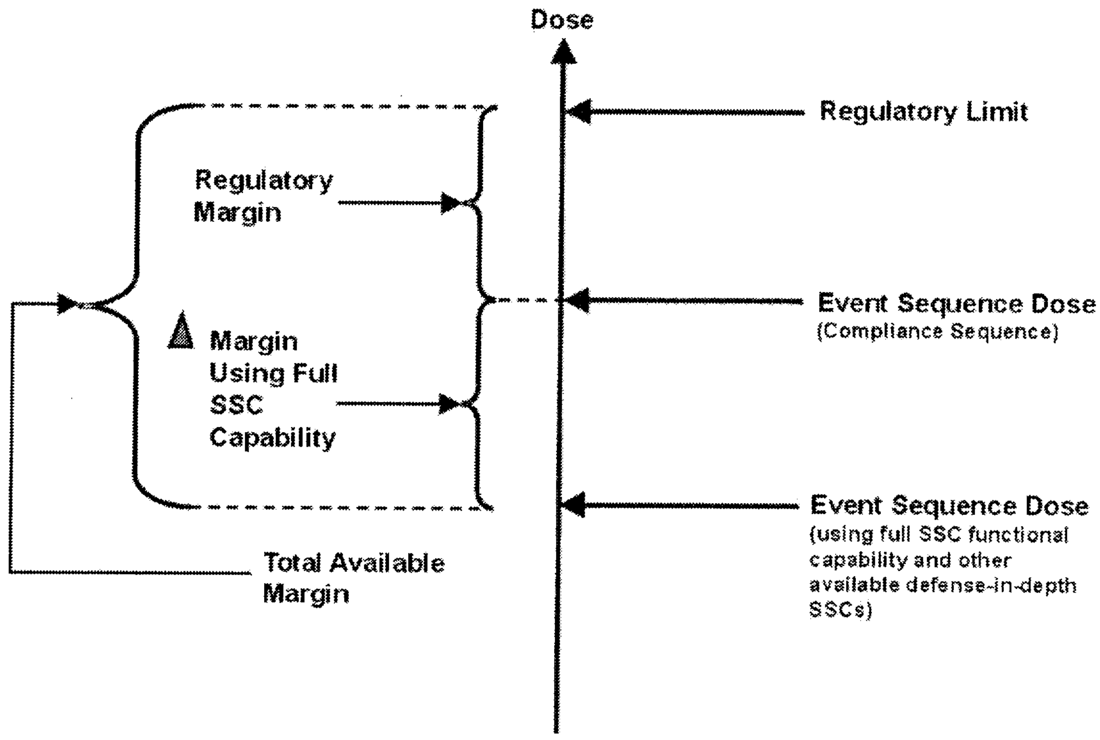
Preclosure Safety Case

(Continued)

- **Margin and Defense-in-Depth**
  - Defense-in-depth - application of redundant or diverse physical and administrative barriers to mitigate unanticipated conditions, processes, and events
    - Risk-informed application of defense-in-depth
    - Facility that is more tolerant of failures and external challenges

Preclosure Safety Case

(Continued)



NOTE: Illustration of typical margin calculations for an event sequence. This event sequence takes credit for the 10 CFR 63.2 design bases functions. The dose calculation for the compliance event sequence is compared to the regulatory limit to provide a regulatory margin. Also shown is the dose calculation for the event sequence that credits the full design bases functional capabilities of the SSCs along with any additional defense-in-depth SSCs. The application of this SSC functional capability would provide additional margin to the regulatory limit that is under control of the Department of Energy.

Preclosure Safety Case

(Continued)

- Consequence analysis of very low probability events and event sequences
  - High consequence sequences (with respect to regulatory requirements)
  - Features required to maintain event sequence as beyond Category 2 evaluated to determine importance to safety
  - Consequence mitigation features would not be considered as important to safety
    - Not required to demonstrate compliance with performance objectives

Preclosure Safety Case
(Continued)

- Nuclear industry precedent and experience
  - Used, as appropriate, in design and analysis of repository operational facilities
  - Factors to consider in evaluating applicability
    - Regulatory basis and/or philosophy
    - Regulatory definitions (e.g., event sequences, safety related, important to safety)
    - Performance objectives
    - Licensing period

Preclosure Safety Case
(Continued)

- Evaluation approach
  - Risk-informed
    - Balancing deterministic and probabilistic approaches
  - Mechanistic
    - Potential causes and effects of failures and actions
- Conservative or bounding approaches
  - Reasonably conservative (e.g., mean frequencies and consequences)
  - Simple bounding, where appropriate
    - Does not overly constrain the design or operations of facility
    - Does not “mask” risk

Preclosure Safety Case
(Continued)

- Preferred Approach
  - Design features over administrative features
  - Passive over active
  - Automatic over manual
  - Separation over colocation

Preclosure Safety Case
(Continued)

- **Retrievability**
  - Geologic repository operations area must be designed to preserve the option of waste retrieval
    - Consequences of Category 1 and 2 event sequences would be within performance objectives
    - No Category 1 or Category 2 event sequences that would preclude the capability to retrieve

Preclosure Safety Case
(Continued)

- **License Specifications and Surveillances**
  - Derived from risk-informed preclosure safety analysis
    - Rules for when important to safety SSCs must be operable
    - Limiting parameters for operation
    - Limits on types and forms of waste to be received

Preclosure Safety Case
(Continued)

- **Preclosure Testing**
  - Testing performed in the preclosure period will be evaluated in PSA
  - Demonstrate operational readiness of the facility

Strategy

- Repository will incorporate a combination of prevention and mitigation
  - Strategy requires prevention, where reasonable
  - Use of design features to reduce event sequence frequency to less than one chance in 10,000
- Will capture strategy that will be employed with evolving design
  - Will be developed in conjunction with Repository Design
- Potential strategy based on SR design presented in Table 3-1

Example Preclosure Safety Strategy

Example Basic Operations	Canistered Fuel Safety Strategy	Uncanistered Fuel Safety Strategy
Receipt of Waste		
Survey Remove impact limiters Remove personal barriers Remove hold downs Upright cask Transfer cask to cart	Prevent events that could exceed shipping cask design basis (preclude breach)	Prevent events that could exceed shipping cask design basis (preclude breach)
Vent and Sample cask Unbolt cask cover Remove cover Remove materials from cask Install cover Bolt cask cover Store canistered waste Store SNF assemblies Decontaminate cask Remove DC cover Load DC Install DC cover Decontaminate DC	Prevent events that could exceed canister design basis (preclude breach)	Minimize the number of events that could result in uncanistered fuel drops; minimize radiation releases from drop events
Sealing the Disposal Container		
Weld DC Inspect DC welds Stress relieve DC welds	Prevent events that could exceed canister design basis (preclude breach)	Minimize the number of events that could result in disposal container drops; minimize radiation releases from drop events
Basic Operations	**Safety Strategy**	**Safety Strategy**
Transfer of the Waste Package (WP) to the Emplacement Drift		
Move WP and pallet to tunnel entrance Descent to drift entrance Park at drift entrance	Prevent events that could exceed WP design basis (preclude breach)	Prevent events that could exceed WP design basis (preclude breach)
Move WP and pallet to tunnel entrance Descent to drift entrance Park at drift entrance	Prevent events that could exceed WP design basis (preclude breach)	Prevent events that could exceed WP design basis (preclude breach)
Emplacement		
Move WP and pallet from tunnel entrance to permanent drift position	Prevent events that could exceed WP design basis (preclude breach)	Prevent events that could exceed WP design basis (preclude breach)

NOTE: DC = disposal container; WP = waste package

Summary

- Strategies for developing preclosure safety case
- Preclosure Safety Strategy
  - Developed based on evolving design
  - Developed in conjunction with design

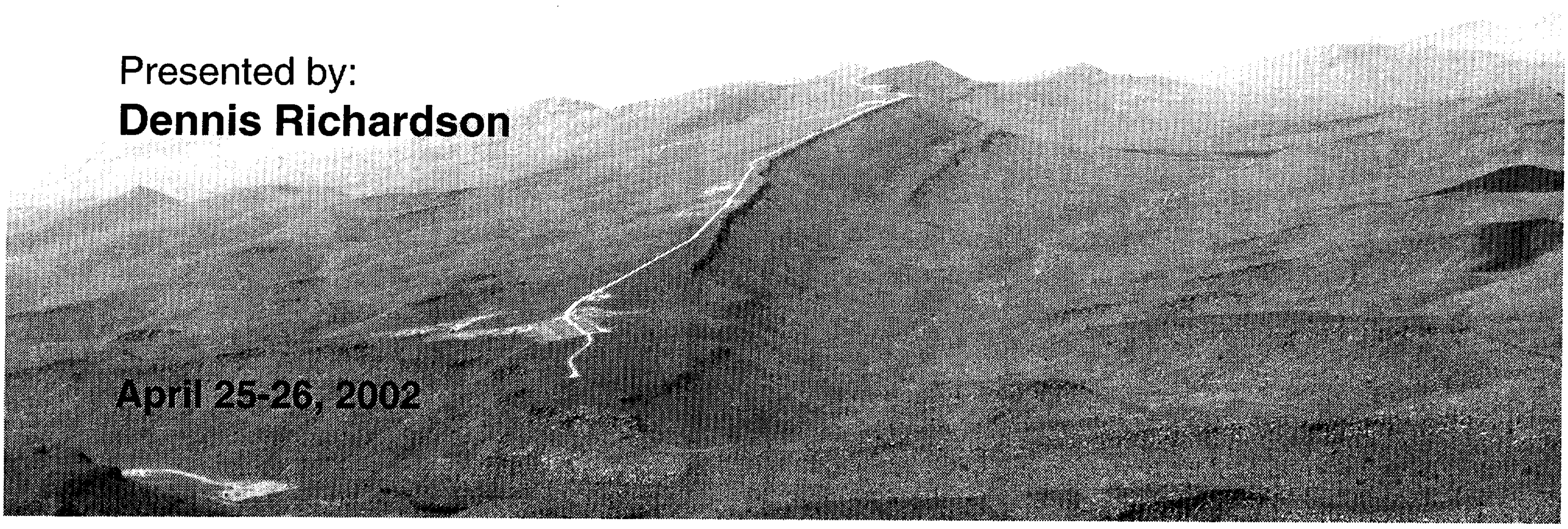
U.S. Department of Energy
Office of Civilian Radioactive Waste Management

YUCCA MOUNTAIN PROJECT

Preclosure Safety Analysis Guide - Overview

Presented to:
NRC Technical Exchange on Preclosure Safety Analysis Guide

Presented by:
Dennis Richardson



April 25-26, 2002

Agenda

- **Purpose**
- **Outline**
- **Section Highlights**
- **Summary**

Purpose

- **Provide an overview of the Preclosure Safety Analysis Guide**

Preclosure Safety Analysis Guide Outline

- Introduction and Overview
- Regulatory Requirements
- Preclosure Safety Strategy
- Overview of Preclosure Safety Analysis Elements and Strategies
- Description of Site, Facilities, and Operations
- Hazards Analysis
- Event Sequence Frequency Analysis
- Consequence Analysis
- Uncertainty and Sensitivity Analysis, General Concepts, and Methods

Preclosure Safety Analysis Guide Outline
(Continued)

- External Events
- Criticality
- Quality Assurance Classification of Structures, Systems, and Components Important to Safety
- Selection of 10 CFR 63.2 Design Bases for Structures, Systems, and Components Important to Safety
- Documentation and Preparation of License Application
- Glossary

Introduction and Overview

- **Purpose**
  - **Provide guidance to Preclosure Safety Analysis Team on methods to meet regulatory requirements**
    - **Preferred, not required methods**
    - **Uniformity in analyses**
    - **Auditable analyses and databases**
    - **Basis for training**
    - **Improved communications**

Introduction and Overview
(Continued)

- **Scope**
  - Guide for preparation of Preclosure Safety Analysis
  - Links for details and background information
  - Recommended methods
  - Risk-informed
  - Events involving natural phenomena, active systems, and human actions in preclosure period

Introduction and Overview
(Continued)

- **Scope**
  - Organized into modules
    - Section 1 - Overview
    - Sections 2-4 - Background information
    - Section 5 - Definition of site and facility design information required as input to PSA
    - Sections 6-9 - Methods for performing hazards analyses, event sequences, consequence analyses, and uncertainty analyses
    - Section 10 - Methods for analyzing external events
    - Section 11 - Preclosure Criticality
    - Sections 12-13 - Processes to select 10 CFR 63.2 design bases and identify SSCs important to safety

Introduction and Overview
(Continued)

- **Scope**
  - Organized into modules
    - Section 14 - Guidance on documenting PSA results
    - Glossary

Regulatory Requirements

- **Summarize regulatory requirements that are key to development of the Preclosure Safety Analysis**
- **Section to be developed later**

Preclosure Safety Strategy

- **General principles**
  - Safety case will address logic, analyses, and calculations that describe how the repository structures, systems, and components meet performance objectives
- **Preclosure Safety case**
  - Preclosure Safety Analysis
  - Margin and defense-in-depth
  - Consequence analysis of very low probability events and event sequences
  - Nuclear industry precedent and experience
  - Evaluation approach

Preclosure Safety Strategy
(Continued)

- **Preclosure Safety case**
  - Conservative or bounding approaches
  - Preferred approach
  - Retrievability
  - License specifications and surveillances
  - Preclosure testing
- **Strategy for Preventing or Mitigating Preclosure Offsite Radiation Exposure**
  - Identification of important to safety features and controls
  - Design bases
  - Safety strategy for preclosure operational functions

Overview of Preclosure Safety Analysis Elements and Approaches

- Overview of process for performing preclosure safety analysis
- Developing and documenting the preclosure safety analysis in the license application
  - License application for construction authorization
    - Level of detail
    - Information base
    - Preclosure safety analysis
- Ensuring performance of SSCs important to safety

Description of Site, Facilities, and Operations

- **Overview**
  - Information that is relevant to performing hazards analyses, event sequence analyses, and consequence analysis
    - Site geography
    - Human populations
    - Natural phenomena and other external events
    - Meteorology
    - Site boundaries
    - Operational and design factors that could affect radiological safety
  - Section to be further developed later

Hazards Analysis

- External hazards analysis
  - Overview of approach
  - Basic approach
  - Examples of application of approach
  - Example external events hazards list
- Internal hazards analysis
  - Overview of approach
  - Evaluating applicability of generic internal events to repository functional areas
  - Examples of application of approach
  - Example internal events hazards list

Event Sequence Frequency Analysis

- **Event tree analysis**
  - Overview of approach
  - Details of approach
  - Examples of application of event tree analysis
- **Fault tree analysis**
  - Overview of approach
  - Details of approach
  - Examples of application of fault tree analysis

Event Sequence Frequency Analysis
(Continued)

- **Human reliability analysis**
  - Overview of approach
  - Details of approach
  - Examples
- **Common-cause and dependent failures analysis**
  - Overview of approach
  - Details of approach
  - Steps in performing dependent failure analysis
  - Examples of application

Event Sequence Frequency Analysis
(Continued)

- **Technical information**
  - Overview of approach
  - Details of approach
- **Event sequence frequency binning**
  - Overview of approach
  - Details of approach
  - Examples of application

Consequence Analysis

- Source terms
- Category 1 offsite doses
- Category 2 offsite doses
- Category 1 worker doses and exposures
- Release fractions
- Mitigation factor

Uncertainty and Sensitivity Analysis, General Concepts, and Methods

- **Overview of approach**
- **Details of approach**
  - Background
  - Identifying sources of uncertainty
  - Representing uncertainty
  - Propagating uncertainty
  - Importance measures analysis
  - Examples

External Events

- **Seismic analysis**
  - **Overview of approach**
  - **Details of approach**
  - **Examples of application of seismic analyses**
  - **Development and application of seismic event trees**
  - **Frequency quantification of seismic sequences using deterministic step-function fragility functions or seismic margins analysis**
  - **Frequency quantification of seismic sequences using fragility functions or seismic margins analysis**

External Events
(Continued)

- **Flooding**
  - Overview of approach
  - Details of approach
  - Flooding protection requirements
- **Winds and Tornadoes**
  - Overview of approach
  - Details of approach
  - Wind and tornado requirements

External Events
(Continued)

- **Sections to be developed further in future revisions**
  - Lighting and extreme weather
  - Fires (internal, external, and wildland)
  - Loss of offsite power
  - Aircraft (after development of vicinity map and license application aircraft hazards plan)
  - Industrial and military hazards
  - Others as needed

Criticality

- **Regulatory requirements**
- **Preclosure criticality safety strategy**
- **Criticality risk analysis**
  - **Identify SSCs and processes associated with criticality hazards**
  - **Identify waste forms that have the potential to achieve criticality**
  - **Develop criticality event trees**
  - **Quantify criticality event trees**
  - **Perform criticality analyses**
  - **Perform criticality consequence analyses**

Criticality
(Continued)

- **Criticality risk analysis**
  - Document the results
- **Category 1 and 2 event sequences will be evaluated for potential criticality**
- **Additional discussion at interactions on criticality**

QA Classification of SSCs Important to Safety

- **Summary of preclosure safety analysis process**
- **Development of a risk-informed classification process**
  - Quality levels and risk significance
  - Risk significant screening criteria
- **Classification process**
- **Functional failure analysis**
  - Category 1 compliance
  - Classification of SSCs associated with Category 1 event sequences
  - Classification of SSCs associated with Category 2 event sequences

Selection of 10 CFR 63.2 Design Bases for SSCs Important to Safety

- **Design Bases (10 CFR 63.2)**
- **Design criteria (10 CFR 63.21)**
- **SSCs required to meet preclosure performance objectivies are identified as important to safety**
- **Design basis established for important to safety SSCs to describe SSC required function**
- **Design criteria established for each important to safety function**
- **Relationship of Repository Design Bases to 10 CFR 63.2 Design Bases and Safety Analysis Report**

Documentation and Preparation of License Application

- **Preclosure Safety Analysis Documentation**
  - Hazards analyses (external, internal)
  - Topical hazards evaluations (e.g., aircraft, wind/tornado, seismic)
  - Event sequence development and categorization
  - Consequence analysis
  - 10 CFR 63.2 Design Basis Report
  - Identification of SSCs Important to Safety/Q-List
  - Preclosure Safety Analysis
- **Preclosure Safety Analysis and LA Submittal**
  - Section to be developed later

Documentation and Preparation of License Application

Hazards Identification → Categorization of Event Sequences → Consequence Analysis → Identification of SSCs and Controls to Prevent and/or Mitigate → Preclosure Safety Analysis

Hazards Identification

LAP/PSA

MGR External Hazards (ANL-MGR-SE-000004)

MGR Internal Hazards (ANL-MGR-SE-000003)

RDP/FD

Fire Hazards Analyses

Categorization of Event Sequences

LAP/PSA

Categorization of Event Sequences

Aircraft Hazards (ANL-WHS-SE-000001)

Wind/Tornado (ANL-MGR-SE-000001)

Industrial/Military (ANL-WHS-SE-000004)

Rainstorm/Flooding

Seismic

Fire Event Sequences

Loss of Offsite Power

HVAC Fault Tree Analysis

Waste Handling Fault Tree Analysis

Component Failure/Reliability Analysis Database

RDP/ACD

Preclosure Event Sequences Related to WP (ANL-MGR-MD-000012)

Preclosure Criticality Evaluations

WP DBE Structural Analysis (Drop Height)

WP Rockfall Analysis

RDP/FD

Transporter Reliability Analysis

Drift Degradation/Rockfall Analysis

Consequence Analysis

LAP/PSA

Potential Consequences of Event Sequences

Potential Consequences of Selected Beyond Category 2 Event Sequences

Commercial SNF Release Fractions (ANL-WHS-SE-000002)

RDP/ACD

Cat 1 Event Sequence Worker Dose Evaluations

ALARA Evaluations

Preclosure SNF Source Terms

Normal releases

ES&H

Radiation Protection Program

Atmospheric Dispersion Factors

Emergency Planning

NSNFP

DOE Fuel Groups/Source Terms

DOE Canister Drop Tests

Pu Can-In-Canister Structural Analysis

Navy

Naval Fuel Event Sequence Source Terms/Releases

Identification of SSCs and Controls to Prevent and/or Mitigate

LAP/PSA

10 CFR 63.2 Preclosure Design Basis Report

Classification Analyses

Q-List (YMP/90-55Q)

RDP

System Description Documents

Design Criteria Document

ENG

Classification Procedure AP-2.22Q

Preclosure Safety Analysis

LAP/PSA

Preclosure Safety Analysis

PSA Guide

Preclosure Safety Analysis License Application Products

Legend:

LAP/PSA - License Application Project/Preclosure Safety Analysis; RDP/FD - Repository Design Project/Facility Design; RDP/ACD - Repository Design Project/Analysis and Component Design; ES&H - Environmental Safety and Health; NSNFP - National Spent Nuclear Fuel Program; RDP - Repository Design Project; ENG - Engineering

Glossary

- Definition of preclosure safety analysis terms
- Understanding
- Consistency

Path Forward

- **Preclusore Safety Analysis Guide updates**
  - Sections to be developed
  - Additional detail, as needed, on existing topics
  - Continuous improvement
    - PSA development
    - Project feedback (design, management, Department of Energy)
    - NRC interactions
  - Next scheduled update - 2002

Summary

- **Additional discussion on selected topics next two days**
  - Strategy
  - Overview of PSA process
  - Hazards analysis
  - Seismic
  - Event sequences
  - Consequences
  - Uncertainty analysis
  - 10 CFR 63.2 design basis
  - Classification process

Summary

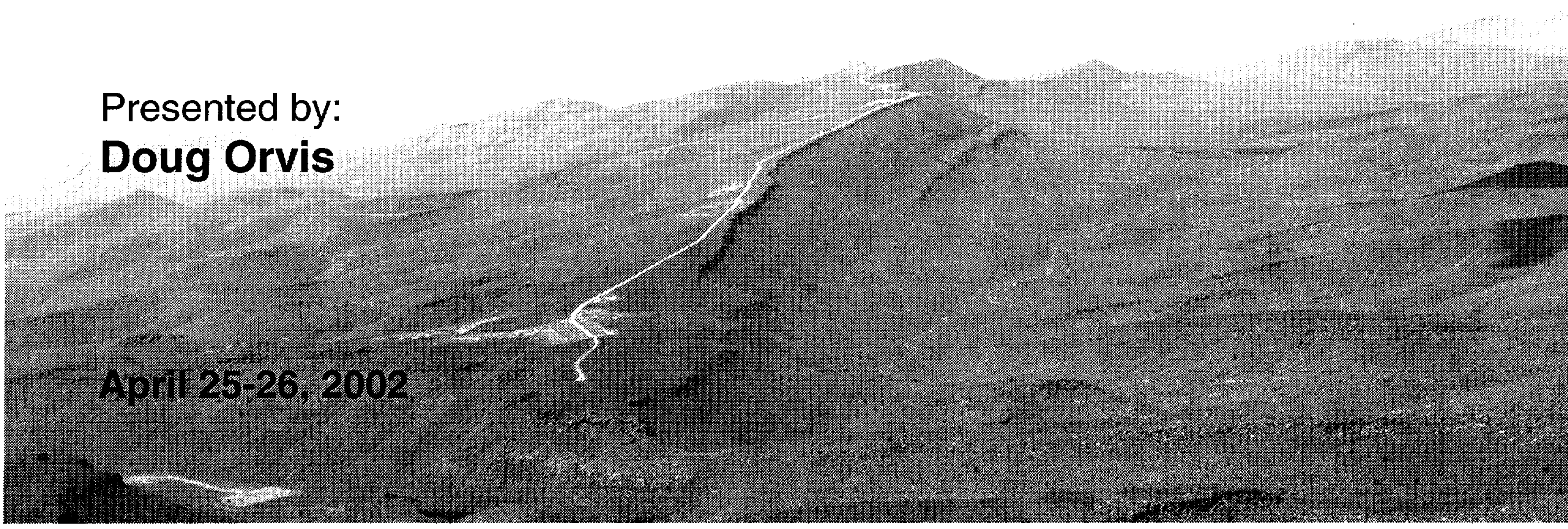
- **Additional topics to be discussed at future interactions**
- **Overview of Preclosure Safety Analysis Guide**
- **Facilitate interactions on preclosure safety analysis methodologies**

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

YUCCA MOUNTAIN PROJECT

Preclosure Safety Analysis Guide - Hazards Analysis

Presented to:
NRC Technical Exchange on Preclosure Safety Analysis Guide



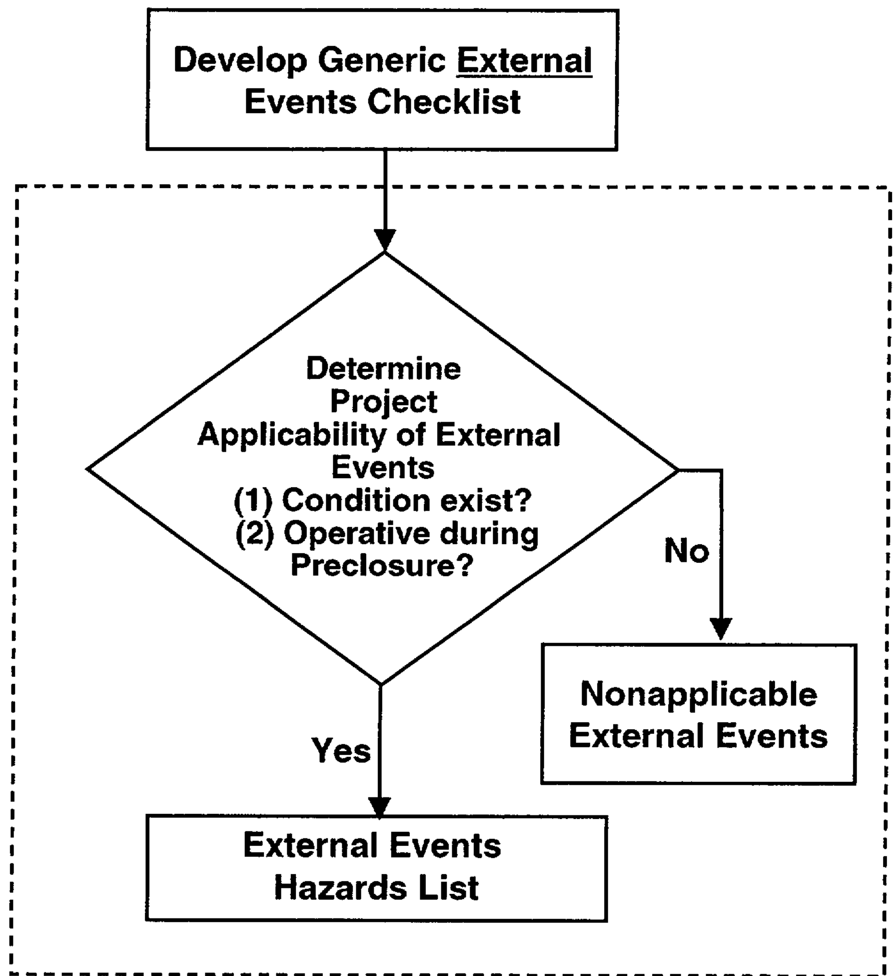
Presented by:
Doug Orvis

April 25-26, 2002

Agenda

- External Hazards Analysis
- Examples
- Internal Hazards Analysis
- Examples
- Summary

External Hazards Analysis Process



Examples Generic External Events

- Aircraft crash
- Avalanche
- Coastal erosion
- Dam failure
- Erosion
- Extreme wind
- Range fire
- Flooding
- Glacial erosion
- Hurricane
- Lightning
- Seismic activity, earthquake
- Tornado
- Volcanic eruption
- Waves

External Hazard Example - Avalanche

- **Definition -**
  - Large mass of snow, ice, solid, or rock, or mixtures of these materials falling, sliding, or flowing under the force of gravity
- **Required Condition -**
  - Steeply sloped terrain found in high mountain ranges
- **Evaluation**
  - Required condition does not exist
- **Applicability**
  - Not applicable

External Hazard Example - Eperogenic Displacement

- **Definition**
  - Geomorphic processes of uplift and subsidence that have produced the broader features of the continents and oceans
- **Required Condition**
  - Geomorphic processes must exist at site
- **Evaluation**
  - Potential exists at site
  - Long term process, not applicable during preclosure operational period
- **Applicability**
  - Not applicable

External Hazard Example - Extreme Wind

- **Definition**
  - Meteorological terms for that component of air that moves parallel to the surface of the earth
- **Required Condition**
  - Meteorological conditions conducive to wind generation must exist at site
- **Evaluation**
  - Potential exists at site
  - Could affect preclosure operational period
  - Event frequency is greater than 1 x 10^{-6} per year
- **Applicability**
  - Applicable

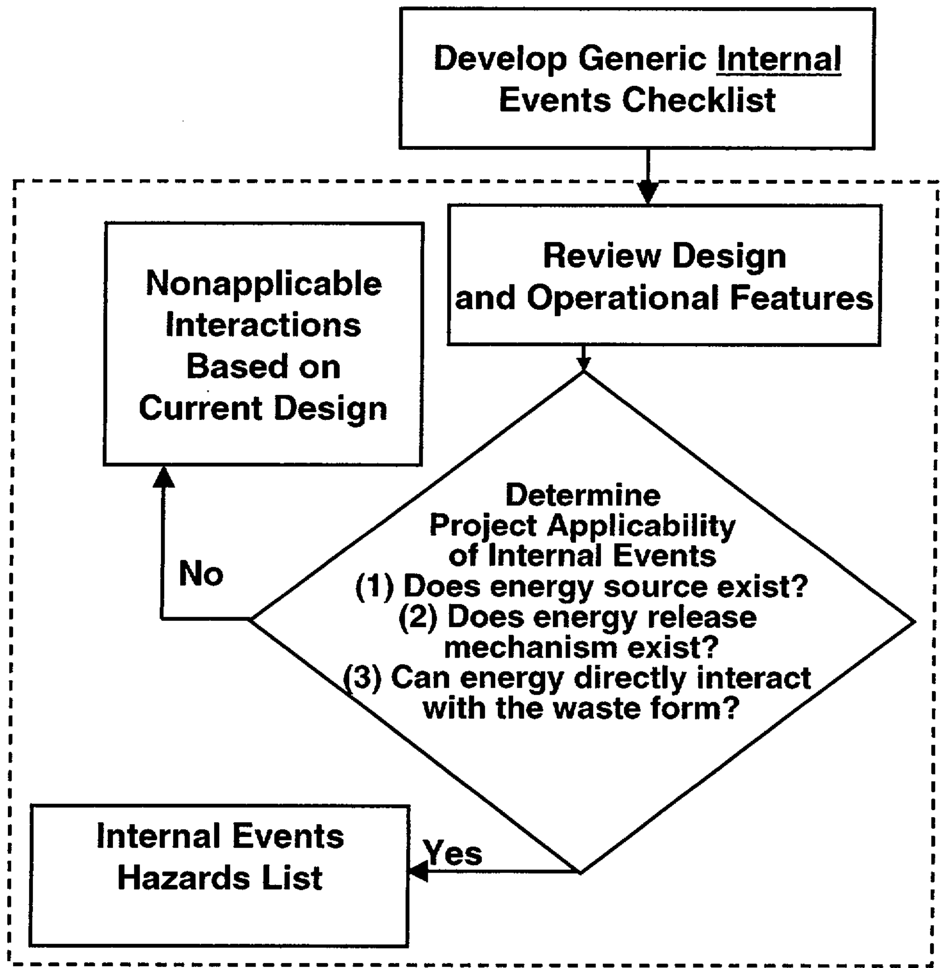
External Hazard Example - Meteorite Impact

- **Definition**
  - Impact of any meteoroid that has reached the surface of the earth without being completely vaporized
- **Required Condition**
  - Potential meteorite impact at site
- **Evaluation**
  - Potential exists at site (meteorites fall randomly throughout surface of earth)
  - Event frequency is less than 1×10^{-6} per year
- **Applicability**
  - Not applicable

External Events Hazards List

- **Example list**
  - Loss of offsite or onsite power
  - Seismic activity
  - Aircraft crash
  - Extreme wind
  - Range Fire
  - Inadvertent future intrusion
- **Represents hazards that require additional evaluation**
  - Potential initiating events
  - May be screened out with additional analysis

Internal Hazards Analysis Process



Internal Hazards Analysis

- **Collision/crushing**
  - Categories
    - Uncontrolled mass/force
    - Protrusions into pathway
  - Applicability to functional area of design
    - Kinetic or potential energy present?
    - Kinetic or potential energy be released in unplanned way?
    - Release of kinetic or potential energy interact with the waste form?

Internal Hazards Analysis
(Continued)

- **Chemical contamination/flooding**
  - Categories
    - Reactions
    - Off-gassing
    - Venting
    - Debris/leaks
    - Flooding
  - Applicability to functional area of design
    - Corrosive or reactive chemicals present?
    - Chemicals or materials released?
    - Chemicals or materials interact with the waste form?

Internal Hazards Analysis
(Continued)

- **Chemical contamination/flooding**
  - Applicability to functional area of design
    - Volatile or condensable materials present?
    - Materials released?
    - Materials interact with the waste form?
    - Potential for venting materials in area?
    - Potential for debris or leaks in area?
    - Sources of water present?
    - Potential to release water?
    - Water interact with waste form with potential for criticality?

Internal Hazards Analysis
(Continued)

- **Explosion/implosion**
  - Categories
    - Pressure energy release
    - Electrical energy release
    - Chemical energy release
    - Mechanical equipment
  - Applicability to functional area of design
    - Pressure, electrical, chemical, or mechanical energy present?
    - Event occur that results in explosion or implosion energy release?
    - Released energy impacts waste form?

Internal Hazards Analysis
(Continued)

- **Fire**
  - **Ignition sources**
  - **Fuel and oxidizer sources**
  - **Applicability to functional area of design**
    - **Fuel, oxidizers, and ignition sources present?**
    - **Sufficient fuel and oxidizer to sustain fire?**
    - **Fire interact with waste form?**

Internal Hazards Analysis
(Continued)

- **Radiation/Magnetic/Electrical/Fissile**
  - Categories
    - Ionizing
    - Non-ionizing
    - Magnetic
    - Nuclear particles
    - Laser light
    - Fissile material

Internal Hazards Analysis
(Continued)

- **Radiation/Magnetic/Electrical/Fissile**
  - **Applicability to functional area of design**
    - **Radiation, magnetic, or electrical energy sources present?**
    - **Fissile material present?**
    - **Mechanism present to release radiation, magnetic, or electrical energy?**
    - **Radiation, magnetic, or electrical interact with waste form?**
    - **Fissile material be arranged to result in criticality?**

Internal Hazards Analysis
(Continued)

- **Thermal**
  - Categories
    - Heat
  - Applicability to functional area of design
    - External thermal energy sources present?
    - Thermal energy be released?
    - Thermal energy affect waste form?

Internal Hazards - Examples

- **Waste Receipt and Carrier or Cask Transport**
  - Generic events applicability
    - Collision/crushing
    - Fire (diesel fire)
    - Radiation
    - Fissile
    - Thermal (fire)
  - Preliminary events
    - Cask collision
    - Railcar derailment involving transportation cask
    - Overturning of truck trailer involving transportation cask
    - Diesel fuel fire
    - Radiation exposure of facility worker
    - Criticality associated with cask collision, railcar derailment, overturned truck trailer and rearrangement of cask internals

Internal Hazards - Examples
(Continued)

- **Waste Handling - Canister Transfer**
  - Generic events applicability
    - Collision/crushing
    - Radiation
    - Fissile
  - Preliminary events
    - Transportation cask slapdown
    - Disposal container slapdown
    - Canister drop
    - Canister slapdown
    - Canister collision
    - Canister drops onto disposal container
    - Canister drop on sharp object
    - Canister drop onto another canister at small canister staging rack

Internal Hazards - Examples
(Continued)

- **Waste Handling - Canister Transfer**
  - Preliminary events
    - Shield door closes on transportation cask
    - Shield door closes on disposal container
    - Handling equipment drops on transportation cask
    - Handling equipment drops on canister
    - Handling equipment drops on disposal container
    - Radiation exposure of facility worker
    - Criticality associated with small canister staging rack
    - Criticality associated with collision or drop of casks and rearrangement of internals
    - Criticality associated with collision or drop of canisters and rearrangement of internals

Internal Hazards - Examples
(Continued)

- **Subsurface Transport, Emplacement, and Monitoring**
  - Generic events applicability
    - Collision/crushing
    - Flooding
    - Fire
    - Radiation
    - Fissile
    - Thermal
  - Preliminary events
    - Transporter derailment outdoors
    - Transporter derailment on ramp or in main drift
    - Transporter collision with other stationary or moving equipment
    - Runaway transporter
    - Rockfall onto tranporter

Internal Hazards - Examples
(Continued)

- **Subsurface Transport, Emplacement, and Monitoring**
  - Preliminary events
    - Loaded emplacement gantry derailment
    - Waste package drop from emplacement gantry
    - Waste package or emplacement gantry collision with equipment or another waste package
    - Rockfall onto waste package
    - Steel set drop onto waste package
    - Failure of isolation air locks due to rockfall
    - Equipment collision
    - Other impacts as a result of development operations
    - Flooding from water pipe break originating on emplacement side
    - Flooding from water pipe break originating on development side

Internal Hazards - Examples
(Continued)

- **Subsurface Transport, Emplacement, and Monitoring**
  - Preliminary events
    - Fire associated with waste package transporter
    - Fire associated with locomotive
    - Fire associated with development equipment
    - Radiation exposure of facility worker
    - Early or juvenile waste package failure and resultant release of radioactive material
    - Criticality associated with collision or drop of waste package and rearrangement of internals

Internal Hazards - Examples

(Continued)

- **Site-Generated Waste Treatment - Liquid Low-Level Radioactive Waste**
  - Generic events applicability
    - Collision/crushing
    - Flooding
    - Radiation
  - Preliminary events
    - Handling equipment drops onto liquid LLW system/components
    - Uncontrolled release of liquid LLW
    - Operator exposure to radioactive material

Internal Hazards Event List

- **Summarizes potential internal hazards that must be evaluated**
- **Example List**
  - Cask collision
  - Railcar derailment involving transportation cask
  - Shield door closes on disposal container
  - Radiation exposure of facility worker
  - Criticality associated with small canister staging rack
  - Steel set drop onto waste package
  - Fire associated with development equipment
  - Uncontrolled release of liquid LLW

Summary

- External hazards analysis process
  - External hazards list
- Internal hazards analysis process
  - Internal hazards list
- Will be used to evaluate repository design to identify hazards

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

YUCCA MOUNTAIN PROJECT

Preclosure Safety Analysis Guide - Seismic Analysis

Presented to:
NRC Technical Exchange on Preclosure Safety Analysis Guide

Presented by:
Douglas Orvis

April 25-26, 2002

Seismic Analysis

- **Purpose:**
  - **Summarize approach to include seismic effects into the Preclosure Safety Analysis**
  - **Describe methods presented in PSA Guide**
- **Scope:**
  - **Overview of approach and discussion of example applications**

Outline

- Background for approach, based on Seismic Topical Report No.2
- Primary method in PSA Guide
  - Steps to apply Seismic TR No.2 for seismic design classification of SSCs using the PSA Guide
  - Application of Event Sequence Diagrams and Seismic Event Trees to define potential release scenarios
  - Examples
- Role of fragility analysis, High-Confidence Low-Probability of Failure (HCLPF), and seismic PRA in PSA Guide
- Approach for risk-informed seismic classification and design bases

Basis for Approach: Seismic TR No.2

- **Defines two vibratory reference earthquakes ground motion (VGM) according to mean annual probability:**
  - Frequency Category 1 (FC-1), 1 x 10 -3 /yr
  - Frequency Category 2 (FC-2), 1 x 10 -4 /yr
  - VGM parameters (e.g., spectral accelerations) being defined for each of the respective earthquakes
- **Classify each SSC important to safety according to which of the two earthquakes, it must perform to**
- **Seismic classification of a given SSC as "FC-1" or "FC-2" based on**
  - performance criteria of 10 CFR 63.111 for event sequence Categories 1 and 2, respectively, and
  - considerations of potential seismically initiated criticality scenarios

Seismic TR No.2 Describes Design Approach for SSCs

- Design of SSCs for seismic considerations
  - Apply applicable portions of Regulatory Guides, SRP, SECY Letters, Industry Codes & Standards
  - Apply ground motion parameters associated with appropriate reference earthquakes (FC-1 or FC-2)
- Approach provides risk-reduction factor so that frequencies of event sequences involving performance of seismic SSCs and releases are implicitly less than 1 x 10 -3 /yr, or 1 x 10 -4 /yr

Seismic Analysis for PSA

- Review design descriptions and drawings for operations, layouts
- SSCs important to safety shall be designed to withstand an FC-1 event, and evaluated to ensure structural functional integrity at an FC-2 event to maintain dose limits at boundaries
- Define scenarios by which an earthquake could result in a potential release of radionuclides or a criticality condition
- Apply event-sequence diagrams and/or seismic event trees to help define seismically induced event sequences and consequence
- Examine both direct or indirect effects of seismically-induced failure of the SSCs

Seismic Analysis for PSA
(Continued)

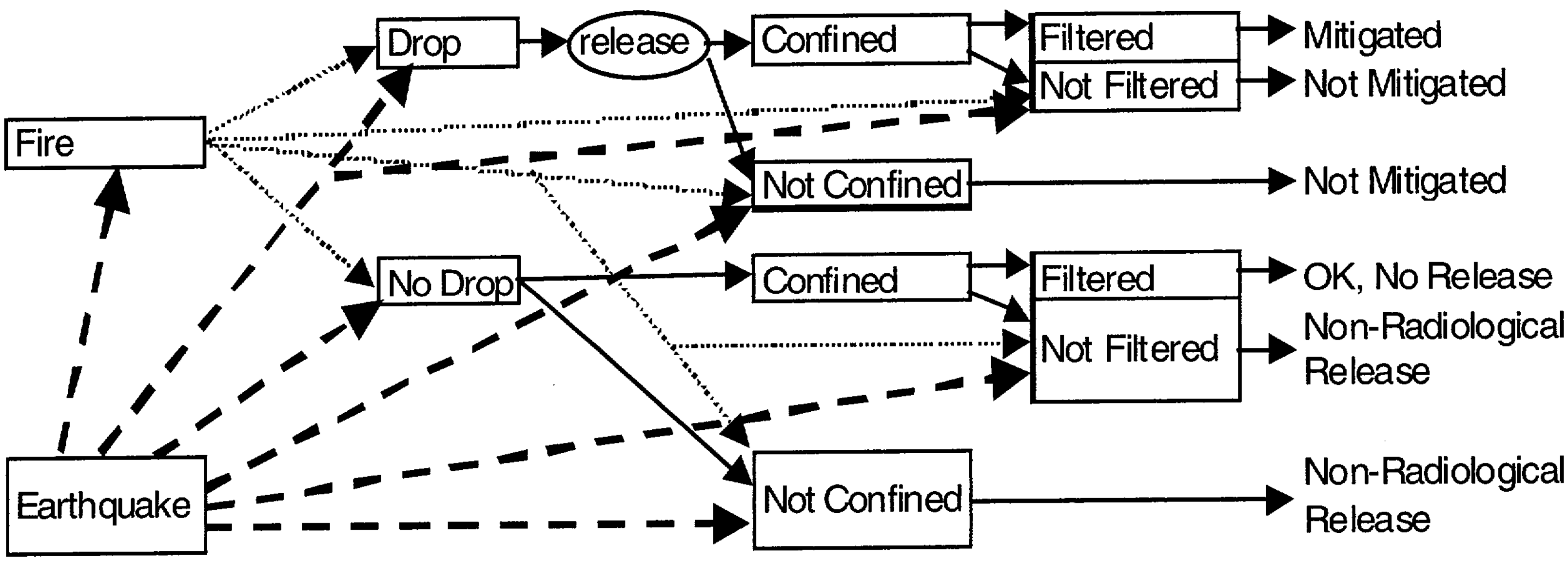
- **Calculate offsite and worker dose**
  - That could result from each hypothetical seismic scenario and the evaluated performance of a given SSC
  - With and without mitigation features that are 1) currently in design, or 2) could be applied

Seismic Analysis for PSA
(Continued)

- Determine the reference earthquake frequency category to apply to each SSC in a seismic event sequence
  - Based on dose calculations and compliance to 10 CFR 63.111
  - Prevention of potential criticality conditions
- Iterate safety analysis and design
- Safety evaluation of performance to demonstrate robust design meets 10 CFR 63

Seismic Scenario Identification: Event Sequence Diagram

Seismic Initiated Fire



Seismic Scenario Identification: Baseline Seismic Event Tree (Hypothetical Example)

Initiating Event: Earthquake	Crane Maintains Functional (1)	No Drop or Breach of WP (3)	Spent Fuel Remains Intact (4)	Confine-ment Maintained in Hot Cell (5)	HVAC Remains Intact and Functional (2)	Seq. No.	Source Term	Offsite Conse-quence (rem)
	yes	NA	NA	NA	NA	1	none	0
	GF or RF	GF	yes	yes	yes	2	C/SC, mitigated	2.00E-03
					GF or RF	3	C/SC, not mitigated	2
				GF or RF	GF - bypass	4	C/SC, not mitigated	2
			no	yes	yes	5	SNF inventory, mitigated	6.00E-03
					GF or RF	6	SNF inventory, not mitigated	6
				GF or RF	GF - bypass	7	SNF inventory, not mitigated	6

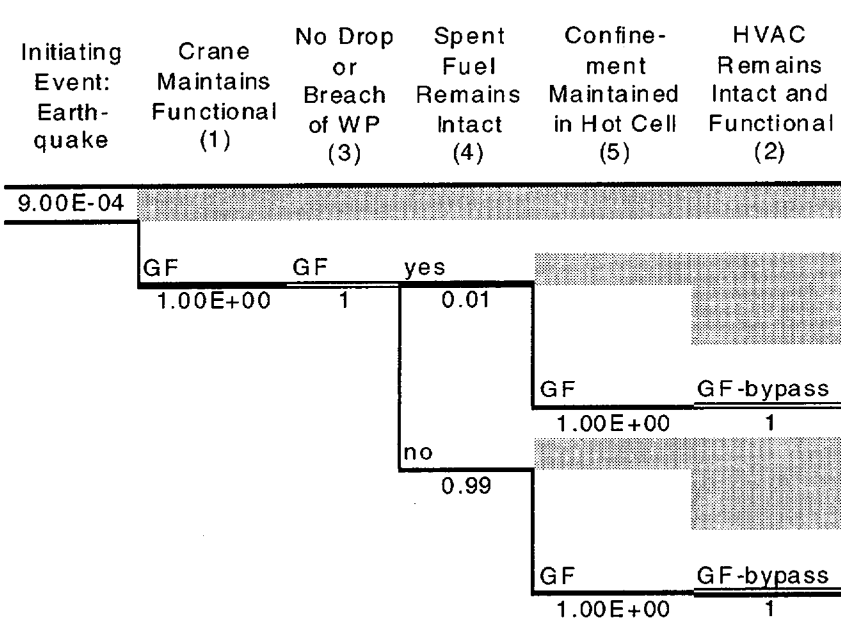
Assumes lifting devices, structure and HVAC could lose safety function during an earthquake

Seismic Classification of SSCs: Application of Seismic Event Trees
(Hypothetical Example)

Initiating Event Earthquake	Crane Maintains Functional (1)	No Drop or Breach of WP (3)	Spent Fuel Remains Intact (4)	Confinement Maintained in Hot Cell (5)	HVAC Remains Intact and Functional (2)	Seq. No.	Source Term	Offsite Consequence (rem)	Frequency
1.00E-03	yes	NA	NA	NA	NA	1	none	0	9.99E-04
	9.99E-01	1	1	1	1				
	RF	GF	yes	yes	yes	2	C/SC, mitigated	2.00E-03	1.00E-08
	1.00E-03	1	0.01	1.00E+00	1.00E+00				
					RF	3	C/SC, not mitigated	2	1.00E-13
					1.00E-05				
				RF	GF-bypass	4	C/SC, not mitigated	2	1.00E-14
				1.00E-06	1				
			no	yes	yes	5	SNF inventory; mitigated	6.00E-03	9.90E-07
			0.99	1.00E+00	1.00E+00				
					RF	6	SNF inventory; not mitigated	6	9.90E-12
					1.00E-05				
				RF	GF-bypass	7	SNF inventory; not mitigated	6	9.90E-13
				1.00E-06	1				

Assumes lifting devices, structure and HVAC designed to FC-1 reference earthquake

Application of Seismic Event Trees with Deterministic Failures
(Hypothetical Example)



Seq. No.	Source Term	Offsite Conse-quence (rem)	Frequency
1	(removed from tree)	0	9.00E-10
2	(removed from tree)	2.00E-03	9.00E-18
3	(removed from tree)	2	9.00E-12
4	C/SC, not mitigated	2	9.00E-06
5	(removed from tree)	6.00E-03	8.91E-16
6	(removed from tree)	6	8.91E-10
7	SNF inventory; not mitigated	6	8.91E-04

Assumes lifting devices, structure and HVAC designed to FC-1 reference earthquake

Role of Fragility, Seismic Margins Analysis and Seismic PRA in PSA Guide

- PSA Guide describes application of fragility as method for evaluating performance vs ground acceleration and for seismic margins analysis
- Discussion in Guide is oriented toward using fragility analysis and seismic margin approaches primarily for confirmatory analyses, i.e.,
  - After design detail is available for structures, component layout (spacing and deminsions), and component anchorage
  - Evaluate performance within functional limits in event sequence frequencies via HCLPF analysis
- Approach in PSA Guide incorporates elements of Seismic PRA

Preliminary Approach to Classification of SSCs and Design Bases

- Risk-informed performance based, using fragility concepts
- Objective of approach is to demonstrate that for any earthquake up to and including motions associated with FC-2, the annual probability of release exceeding 10 CFR 63.111(b)(2) doses is less than 1 x 10 -6 /yr
- Seismic classification of SSCs and associated design bases become risk-informed performance based

Preliminary Approach to Classification of SSCs and Design Bases
(Continued)

- **Hypothetical example (based on event tree for drop of WP)**
  - Application of dose criteria indicates that structure must maintain the confinement function for FC-2 seismic event (Sequence 7)
  - Define definitive failure criteria for functions, e.g., cracking without loss of confinement may be acceptable for hot-cell confinement
  - Establish seismic design criteria for confinement structure as FC-1 using substantial margins with respect to loss of functional integrity
  - Apply fragility analysis to show conditional probability of loss functional integrity for confinement for FC-2 earthquake is sufficiently low

Status of Approach

- Method is under study by inter-departmental team
- Uses elements presented in PSA Guide
- Uses guidance provided by YMRP, SECY Letters, NUREGS, and 10 CFR 63
- Subject of future discussions with the NRC

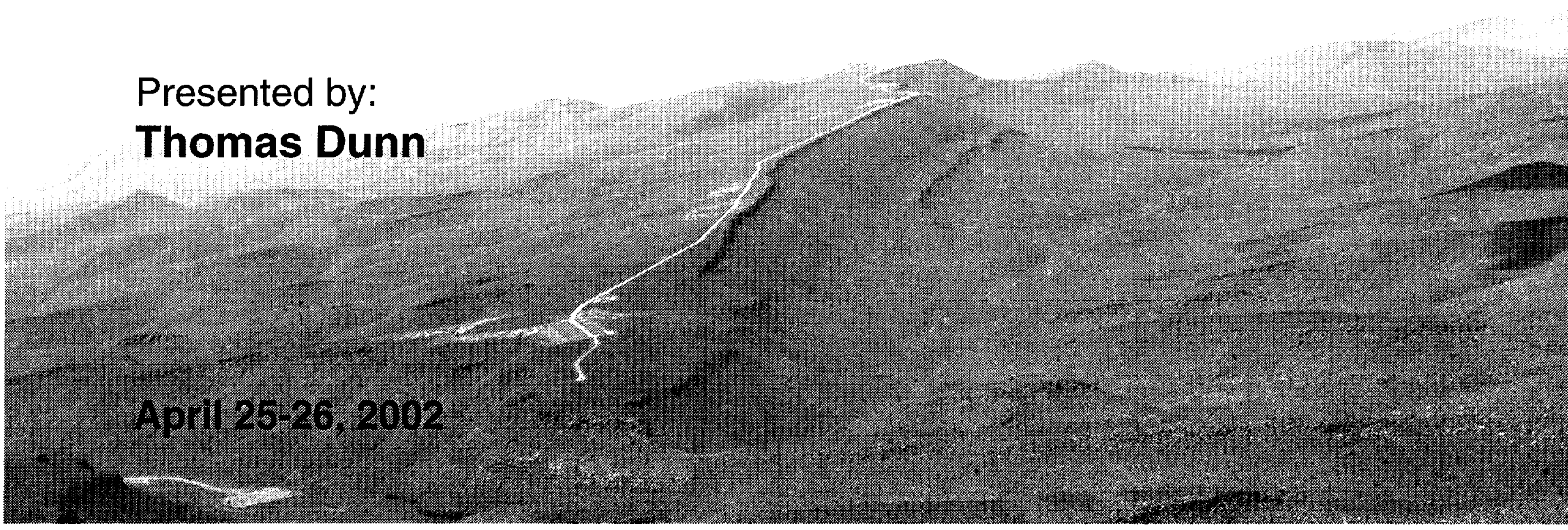
U.S. Department of Energy
Office of Civilian Radioactive Waste Management

YUCCA MOUNTAIN PROJECT

Preclosure Safety Analysis Guide - Event Sequences

Presented to:
NRC Technical Exchange on Preclosure Safety Analysis Guide

Presented by:
Thomas Dunn



April 25-26, 2002

Introduction

- **Event Tree (ET) and Fault Tree (FT)**
  - **Methods and Processes extracted from**
    - **Fault Tree Handbook (NUREG-0492)**
    - **Human Reliability Handbook (NUREG-1278)**
    - **ATHEANA (NUREG-1624)**
    - **PRA Procedure Guide (NUREG/CR-2300)**
    - **Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications Final Report (NUREG/CR-1278)**

Event Tree Analysis

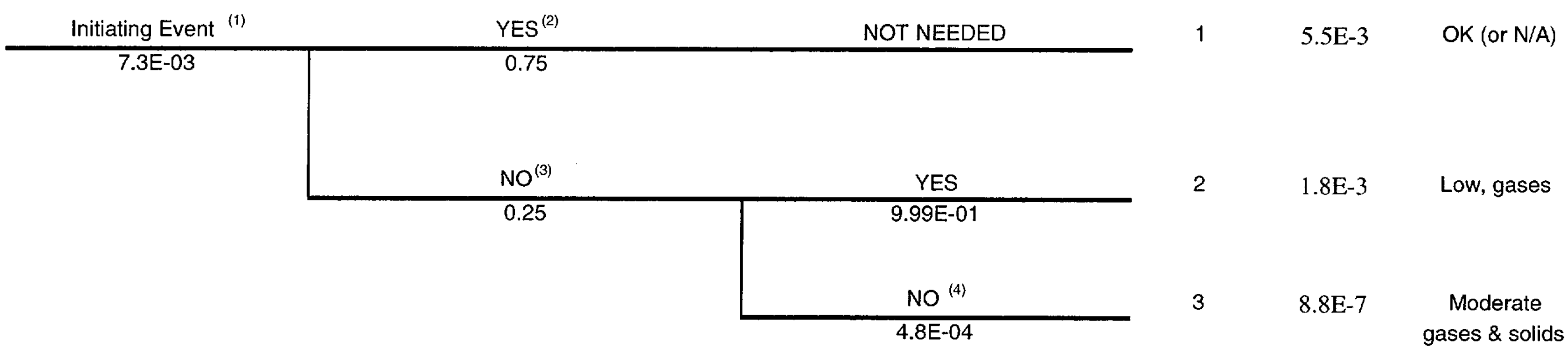
- **Purpose**
  - Methodology for construction and use of event tree analysis (ETA) used to:
    - Identify event sequences that could result in radioactive releases or exposures
    - Identify and quantify dependencies between events in a sequence
    - Identify the magnitude of system failure or damage that results in potential releases or exposures
    - Quantify the event sequence frequency
    - Quantify the event sequence uncertainty

Event Tree Analysis
(Continued)

- **Overview of Approach**
  - An ET is a graphical logic model that identifies the possible outcomes following an initiating event (IE)
  - ET format provides a framework for estimating the likelihood of event sequences by displaying the frequency of the IE and the conditional probabilities of contributing (enabling) events
  - Construction of ETs will build, primarily, on the IEs or event categories identified in the internal events hazards analysis (see Section 6.2)
  - ETs are a tool to define the manner in which failure paths may occur, as well as a framework for quantifying the frequencies of the various success and failure paths constructed as required for the events identified by the External Events Hazards Analysis (see Section 6.1)

Example Event Tree

DROP OF WASTE FORM	WASTE FORM MAINTAINS CONTAINMENT	HVAC/HEPA AVAILABLE			
Drop of Waste Form onto Unyielding Surface	Cond. Probability: drop height within design basis of Waste Form Container	Probability that HVAC/HEPA is available upon demand	**Sequence Identifier**	**Frequency (per year)**	**Release Severity**



Notes:
(1) Initiating event is due to unspecified failure in the lifting crane. From generic data, the frequency of initiating event is estimated to be 524 lifts/yr x 14 drops/million lifts
(2) Drop from normal height or less than design basis.
(3) Drop exceeds design basis due to 2-block event. Conditional probability of 2-block event is assumed to be 0.25 for this illustration.
(4) Unavailability of HVAC/HEPA derived from fault-tree analysis of HVAC/HEPA system.

Event Tree Analysis

- **Quantification of event probabilities and sequence frequencies**
  - **IEs frequencies for internal hazards are estimated from the annual frequency of each operation multiplied by the probability per opportunity (or per operation) that the IE occurs**
    - **For example, the frequency of a canister drop is estimated by the product of the frequency of canister lifts (i.e., the number per year) and the conditional probability of dropping the canister per lift**
  - **Conditional probability of each enabling event (usually a failure of some preventive or mitigative feature) is estimated from facility-specific data (if available) or generic data for similar operations**

Event Tree Analysis
(Continued)

- **Quantification of event probabilities and sequence frequencies** (Continued)
  - In the preliminary binning, frequencies of IEs and probabilities of enabling events are conservatively estimated and multiplied to estimate the frequencies of event sequences. The conservatism's are thereby stacked
  - In the refined analyses, probability distributions are defined for the IE frequencies and event probabilities to represent uncertainties and are propagated to derive probability distributions for sequence frequencies. The mean value of frequencies of event sequences will be used for binning the results as Category 1 or Category 2 event sequences

BECHTEL SAIC COMPANY, LLC

Event Tree Construction-Steps

Become familiar with design and operation of the system. Using results of hazards analysis as guide. Identify safety functions and features that mitigate identified hazards. If necessary, develop functional diagrams and/or process flow diagrams to help identify where initiating events may occur and how event sequences may develop.

↓

1. Identify Initiating Event. Identify all initiating events for a given system. A separate event tree will be developed for each initiating event. Several operations in a given system may admit an initiating event that could be a potential hazard to a waste form. A list of all specific initiating events is generated. The hazards analysis may have provided a list of specific initiating events or a list of general categories of initiating events.

↓

2. Identify Safety functions and Conditioning Factors (Event Tree Headings)
Event tree headings are defined primarily to represent the safety features that have to succeed or fail to propagate an event sequence. Event tree heading may also define conditioning events such as the presence of extreme temperature, fire, or human action that could affect the need for, or conditional probability of, a subsequent event in a sequence. Phrase event headings as "success" of safety feature or as presence of "favorable" conditioning events or human actions.

↓

3. Construct/Edit Event Tree
Starting with initiating event, construct initial event tree by listing event headings from left to right. Generally, headings are listed in chronological order. Conditioning events may be inserted where appropriate. Draw branches by connecting nodes under each event heading. Account for dependence on preceding events and conditions. After examination of results after Steps 4 or 5, it may be possible or preferable to edit tree by rearranging order of headings, deleting headings, or adding new headings, as appropriate.

↓

4. Classify Outcomes, System States, or Consequences of Each Sequence
The end states represent conditions that affect the consequences associated with a given sequence. Categories may be qualitative, but generally are defined by quantitative measures of radioactivity available for release. The consequence classification establishes initial conditions for consequence analyses. The outcome of each sequence is defined by consideration of the various successes and failures of safety functions (or conditioning events) occur between the initiating event and the end point.

↓

5. Quantify Initiating Event Frequency and Probabilities of Branches
Estimate frequency of each initiating event from the annual frequency of each operation times the conditional probability of the initiating event per operation. The conditional probability of each branch under a heading in an event tree (other than the initiating event) corresponds to a probability of the outcome (i.e., the event is TRUE or FALSE) that is conditional on the occurrence of the preceding event. The sum of the probabilities of the two branches of each limb must total to 1.0. Usually the probability of the TRUE (or YES) branch is close to 1.0 by itself since it is the expected successful availability of a safety function or a nominal environment. The FALSE (or NO) branches are usually low probability events (small fractions). The probability of the failure of a safety feature, an undesirable human action, or a less desirable condition is estimated from generic data for similar operations or from experience data if available. Total dependencies such as "guaranteed failure," "guaranteed success," and "not needed" are assigned conditional probabilities of 1.0.

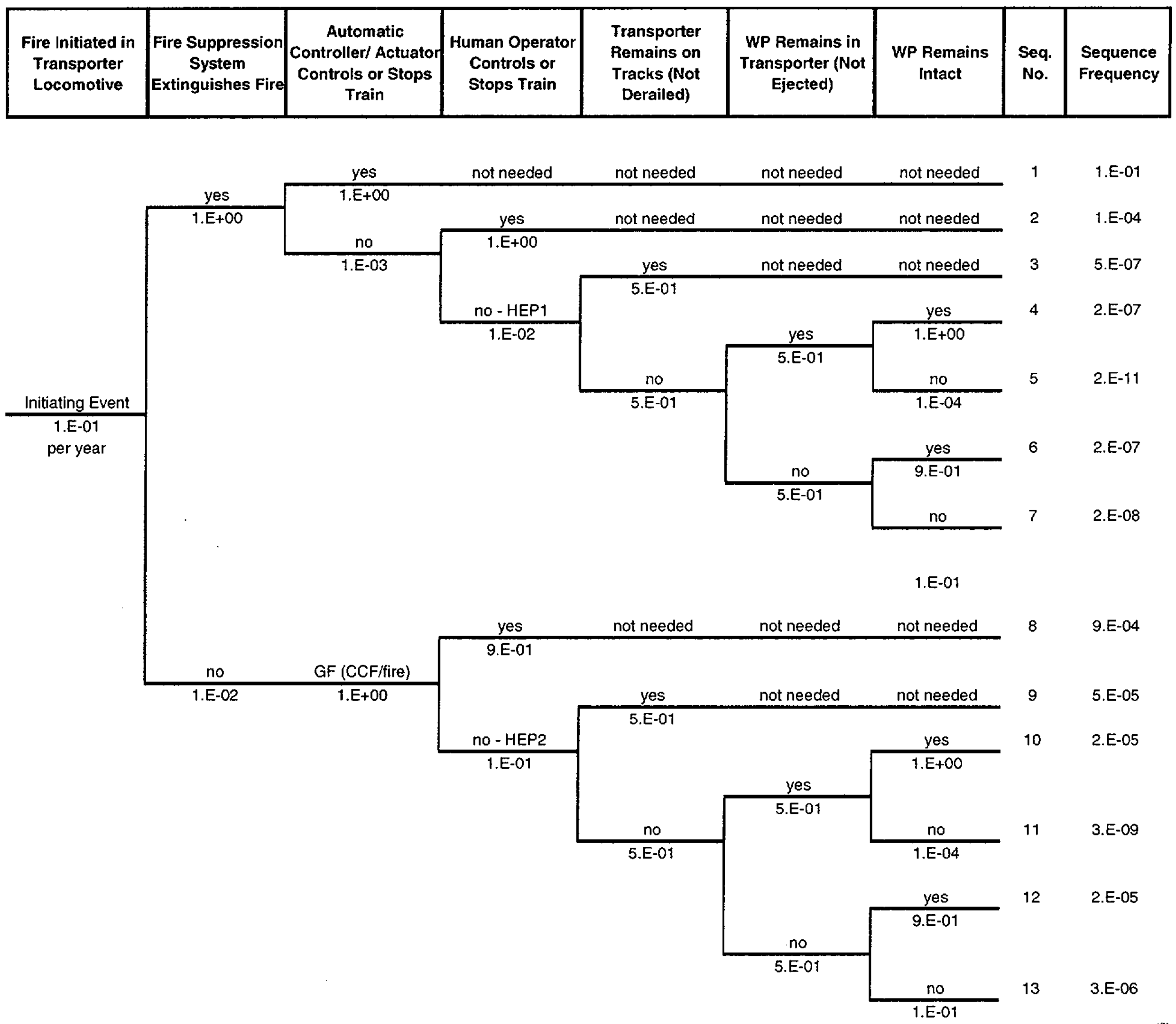
↓

6. Quantify Sequence Frequencies
For each sequence defined by a pathway from initiating event to end state in the event tree, quantify the sequence frequency by multiplying the initiating frequency by the conditional probabilities of all events in a sequence.

↓

7. Review/Test Results
Review the results of the event tree analysis to ensure that the outcomes are physically possible, accurately defined and quantified, and complete. Review team includes event tree analyst and cognitive personnel (e.g., from design, operations, radiological consequence analysts, radiation protection program, and safety-specific areas.)

Example Event Tree (Fire initiated)



Fault Tree Analysis

- **Purpose**
  - Define the basis and methodology for the construction and use of FTA
  - FTA has application in
    - Quantifying the frequency of IEs as well as the conditional probability of enabling events that contribute to event sequences
    - Explicit modeling and quantifying of dependencies between primary (front-line) safety systems and support systems
    - Top-down modeling of combinations of events that lead to an undesired outcome, including development of master logic diagrams
    - Providing a structure for propagating uncertainties in basic events to the top event

Fault Tree Analysis
(Continued)

- **Overview of approach**
  - **FT models maps physical systems into a logic model based on deductive logic**
    - **Deductive model begins at some undesired event (or consequence), such as release of radioactivity from surface facility--top event**
    - **Based on the top event model identifies (deduces) all of the causes of the undesired event**
    - **Model is developed downward from the top event and usually stops at the basic event level**
    - **For example "release of radioactivity from surface facility," would proceed from facility to building to operation to system to subsystem to the basic events that are failures in specific hardware components, software, electronic control or logic elements, human errors, or loss of essential support functions, such as loss alternating current (AC) electrical power**

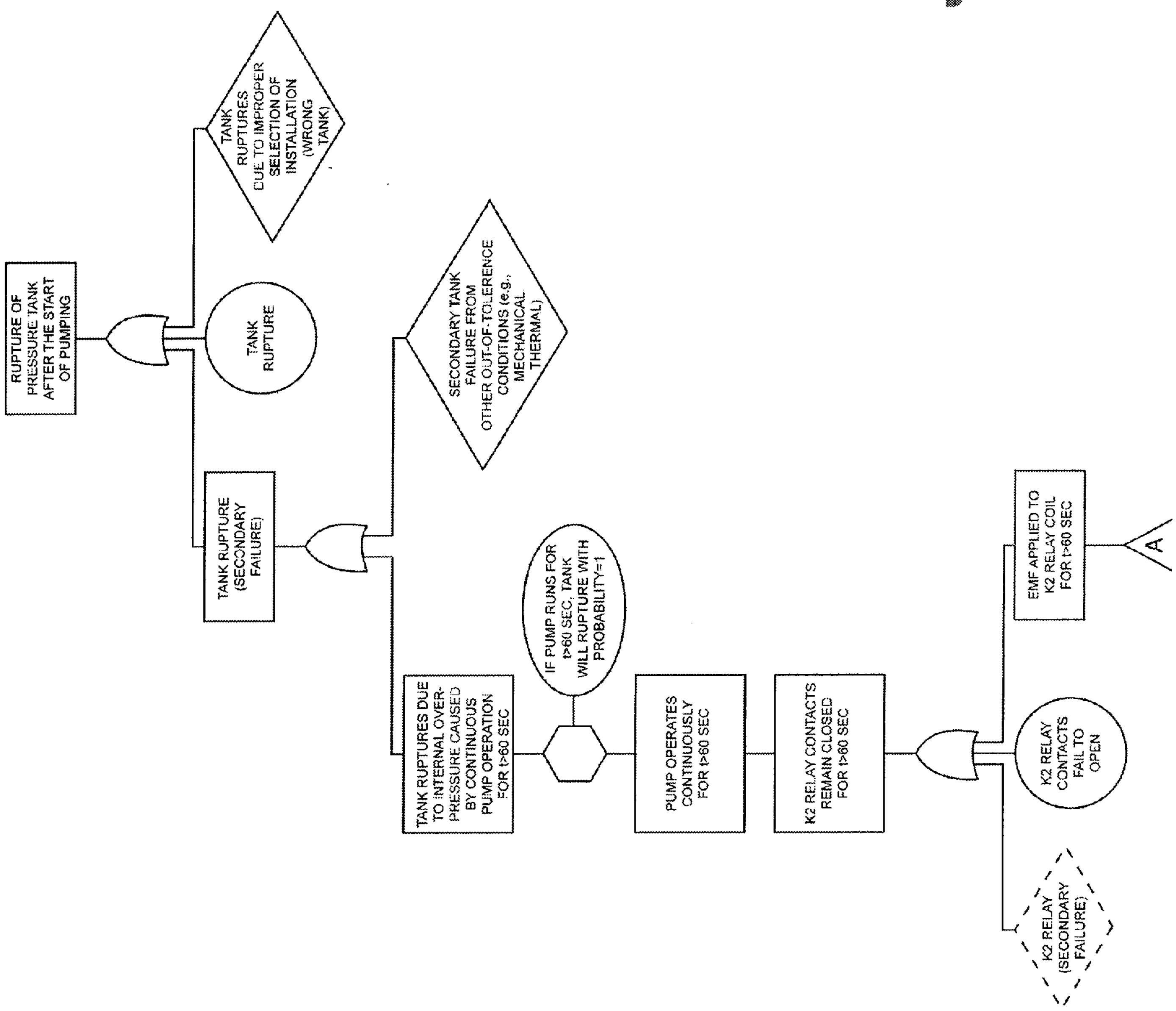
Fault Tree Analysis
(Continued)

- **Guidance on fault tree construction**
  - ***Fault Tree Handbook*** **is referenced in the guide--this handbook develops rules for FT construction. The analyst is referred to Chapter V of the *Fault Tree Handbook***
    - **Rule 1 Top Event Definition**
    - **Rule 2 Development of Immediate Cause**
    - **Rule 3 Complete the Gate**
    - **Rule 4 No Miracles**
    - **Rule 5 Development of Intermediate Events**
    - **Rule 6 Identify Potential Dependent or Common Cause Failures**

Fault Tree Analysis
(Continued)

- **Basic Event Quantification of component faults in a fault tree is described in the PSA guide and includes:**
  - **Failure on demand**
  - **Standby failure**
  - **Operational failure**
- **Descriptions are given for how failure per demand or failures per hour are obtained from experience information**
- **Unavailability with and without repair is defined**

Fault Tree Analysis



Human Reliability Analysis (HRA)

- **Purpose**
  - **Provide methods for analyzing HRA in event sequence development and frequency quantification**
- **Approach**
  - **Based on methods developed by NRC and EPRI that have been applied in prior PRA and IPE studies, and latest (i.e., ATHEANA)**

HRA Overview

- **Uses systematic process to identify, screen, analyze, model, and quantify probabilities of human failure events (HFEs) and their effect on event sequence frequencies**
- **Quantifies probabilities of HFEs using techniques developed for PRA applications**

Identification and Screening

- Identify potentially significant human actions (HAs) in event tree or fault tree models
- HAs may be expected responses or recoveries; HFE is failure to perform HA or error of commission
- Apply screening rules to reduce number of HAs requiring detailed analysis

Detailed Analysis and Quantification

- **Task analysis: breakdown of HA into specific steps, including action to be performed, where, time restrictions, and/or inputs/instrumentation needed; opportunity for recovery**
- **Representation: logic model based on task analysis, e.g., HRA fault tree, operator action tree**
- **Modeling: equation used to quantify the probability of HFE**
- **Quantification: inserting values into model (including effects of influence factors) to obtain probability of HFE and uncertainty**

Different Representation and Models used for Types of HAs

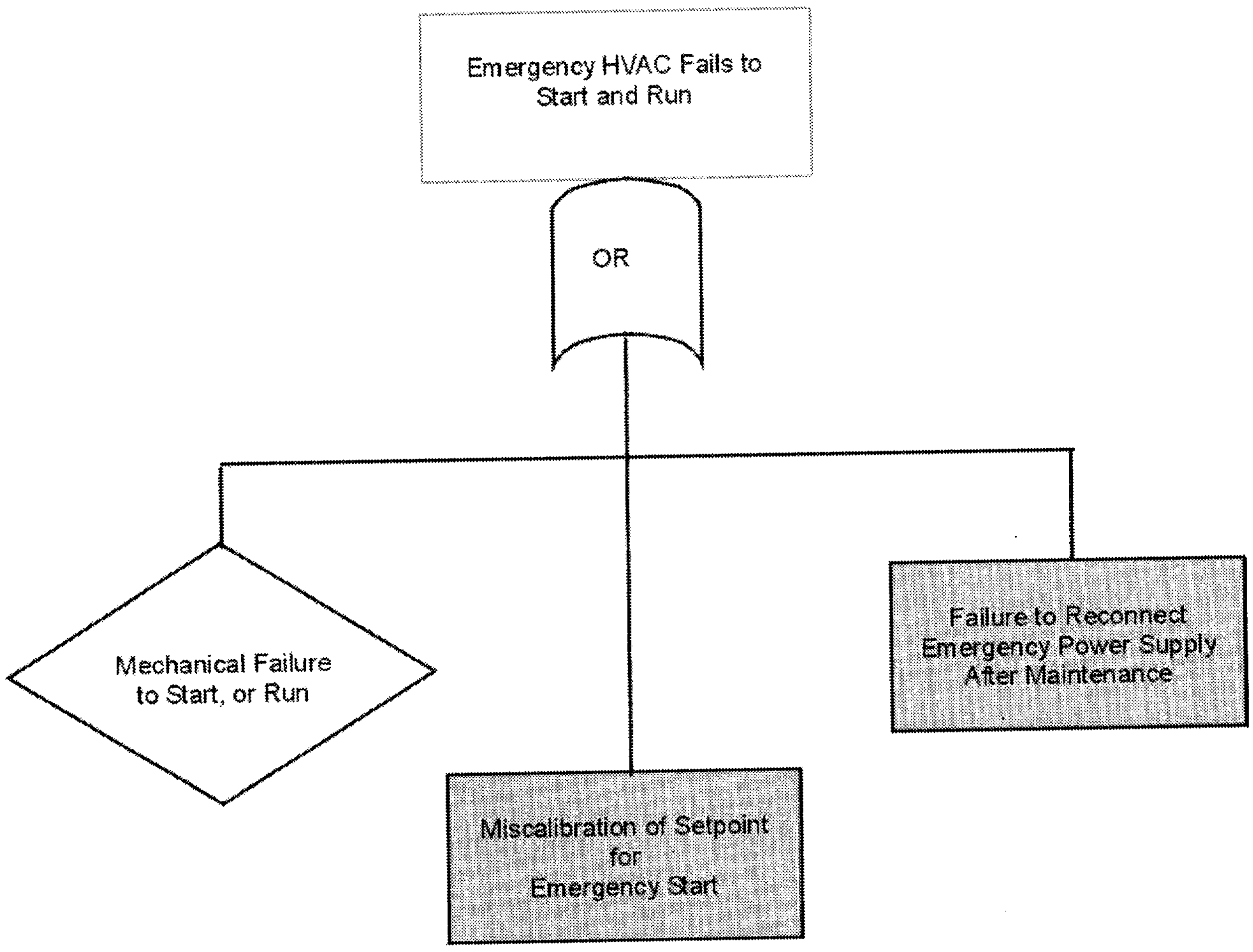
- Type A: occurs before initiating event; e.g., testing and maintenance; effect on system unavailability can be included as basic event in fault tree; quantify probabilities using HRA Tree & tables from Human Reliability Handbook (NUREG-1278)
- Type B: contribute/cause initiating event; generally implicit in experience data in PRA studies, but may need to identify and quantify new IEs for first-of-a-kind facilities; quantification similar to Type A
- Type C: responses and recoveries after initiating event to arrest sequence or mitigate; includes errors of omission and errors of commission

Different Representation and Models used for Types of HAs

(Continued)

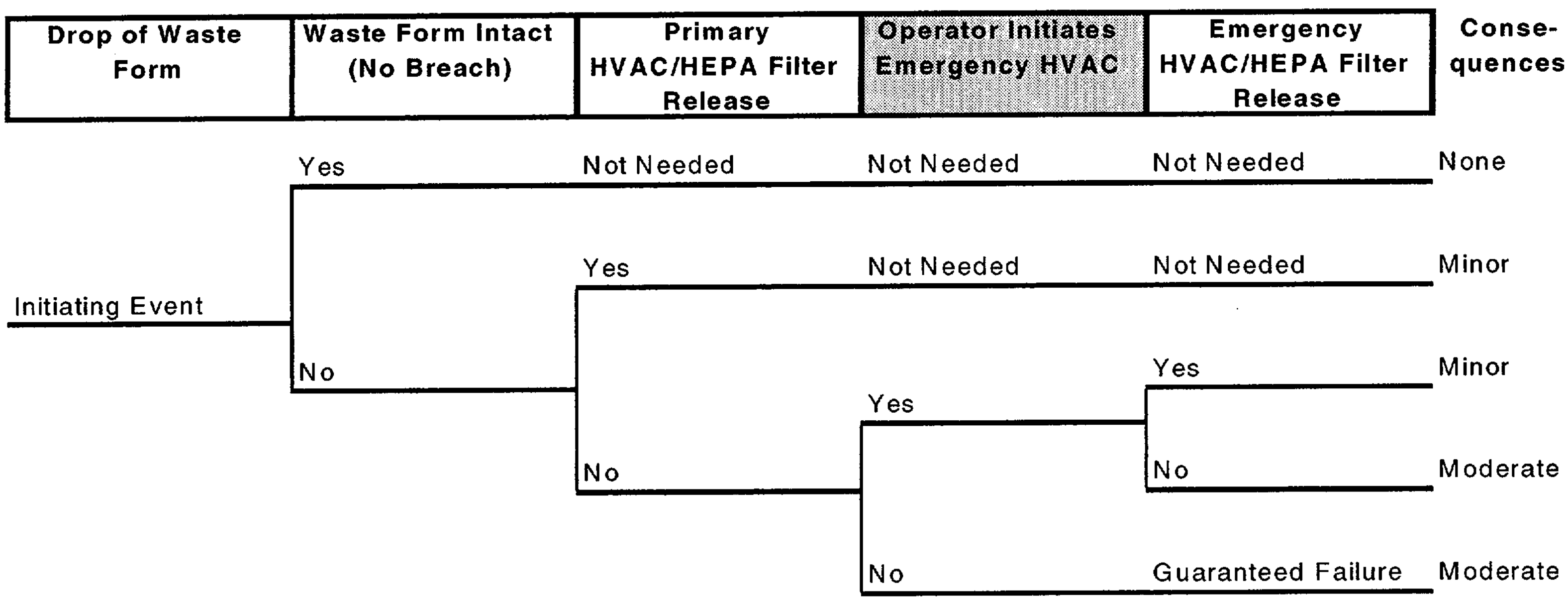
- **Type C: responses and recoveries after initiating event to arrest sequence or mitigate**
  - Can be procedure driven (CP), or not
  - Can represent recovery actions (CR)
  - Can be errors of omission or commission
- **Several methods available for quantification, including portions of NUREG-1278 and some aspects of ATHEANA (NUREG-1624, Rev.1); will apply method appropriate to task breakdown and significance of HA to preclosure risk**

Example of Fault Tree Containing Type A Human Actions

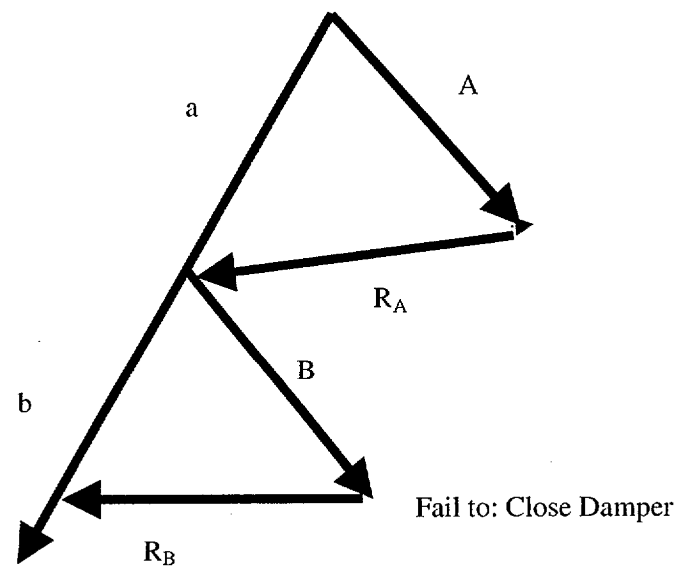


Event Tree with Type C Human Action in Event Headings

Example of Event Tree with Human Action in Event Headings



Example HRA Tree: Operator Fails to Initiate Emergency HVAC (NUREG-1278)



Probability of Human Failure to Start HVAC = A + B

Example Quantification of Probability of HFE

$p_3 = HEP_A * R_A + HEP_B * R_B$

Using HEP values from NUREG-1278,

HEP_A = 0.001 (EF=3); HEP_B = 0.003 (EF=3);

and non-recovery factors R_A = 0.1 (EF=3); R_B = 1.0

p_3 = (0.001)*(0.1) + (0.003) * (1.0) = 0.0031 (EF >3)

Insert p_3 into event tree for failure branch under heading "Operator Initiates Emergency HVAC" and quantify frequency of event sequence

Common-Cause and Dependent Failure Analysis

- **Purpose**
  - PSA guide defines the bases and methods for identifying and analyzing common-cause and dependent failures
  - Common-cause failures (CCFs) and dependent failure analyses support event sequence analyses through applications in ETA and FTA

Common-Cause and Dependent Failure Analysis

(Continued)

- **Overview of approach**
  - Method(s) used to identify dependent failures in SSCs
  - Application of qualitative versus quantitative evaluations
  - Quantitative methods when evaluating Fault and Event Trees
  - Data requirements and sources
  - Treatment of external events as potential common-cause initiating events and how dependent failures of SSCs are conditionally linked to external hazard frequency
  - Differences in approach and level of design detail for the LA submittal for CA in contrast to the LA submittal to receive and possess nuclear materials
  - Application of software packages (e.g., SAPHIRE)

Common-Cause and Dependent Failure Analysis

(Continued)

- **Details of approach**
  - Implicit modeling of dependent failures can be modeled and quantified using the β Factor method--assumes that a fraction β of reported component failures is due to common cause and the remainder is due to independent failures
    - For example the common cause failure of a multiple redundant trains can be modeled using a β factor
  - Explicit dependencies are modeled directly within ET tree or FT, e.g.:
    - In ET, fire may initiate event that causes a load drop and failure of the HVAC/HEPA modeled as dependant failure
    - In FT, dependence on elective power modeled as transfer

Technical Information

- **Purpose**
  - Guide defines the bases and methods for gathering and quantifying technical information that is used in the quantification of FTs and ETs
    - Technical information needs for ET and FT quantification consist generally of IE frequencies, failure rates and probabilities, CCF parameters, HEP, mission times, repair times, inspection intervals, and demand rates
    - Section also describes the methods for quantifying the uncertainty factors in the parameters based on concepts described in Section 9

Technical Information
(Continued)

- **Overview of Approach**
  - **The selection of techniques for producing the parameters and sources of information upon which to base the parameters follows the *PRA Procedure Guide***
  - **The following elements from the PRA Procedure Guide are discussed:**
    - **Selection and Use of Event Models**
    - **Information (Data) Gathering**
    - **Estimation of Model Parameters**
    - **Uncertainties in Information and Event Probabilities**
    - **Documentation**

Technical Information
(Continued)

- **Details of Approach**
  - Overview of failure models due to random causes is presented such as
    - Failure on demand – probability of failure per demand
    - Standby failure – probability of failure on demand after a given non-operational period, usually given as time-between-inspections
    - Operational failure – probability of failing to run or operate (provide required function) during a specified time period (i.e., the mission time)
  - Besides failures due to random causes, failures may also be caused by:
    - Human errors in T&M that leave the equipment or software in a disabled state
    - Human errors during operation that cause a loss of the safety function

Technical Information
(Continued)

- **Details of Approach (Continued)**
  - Operational Experience may be used on similar equipment to estimate the number of failures or failure rate of equipment
    - In some instances the operational experience maybe need to be adjusted for the repository
  - List of representative sources of technical information include:
    - Exploratory Studies Facility
    - U.S. Department of Transportation, Federal Railway Association
    - British Mining Locomotive Data
    - *Technical Assessment Generic Issue 186 Potential Risk and Consequences of Heavy Load Drops in Nuclear Power Plants*

Technical Information
(Continued)

- **Details of Approach** (Continued)
  - Tabulations of generic information may also be used to support the PSA, a bibliography is provided in Appendix 7A
  - Selected databases sources are listed below:
    - Savannah River Site Human Error Rate Database
    - *IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems*
    - NUCLARR, NUREG/CR- 4639
    - Generic Component Failure Data Base

Event Sequence Frequency Binning

- **Purpose**
  - **Guide defines the bases and methods for applying the results of the ET sequence quantification to categorize (or bin) credible event sequences as Category 1 or Category 2 according to the definitions of 10 CFR 63.2**

Event Sequence Frequency Binning
(Continued)

- ## Overview of approach
  - Screening criteria is derived from 10 CFR 63 assuming the facility is preclosure operation in 100 years then:
    - Category 1 event sequences have a frequency great than or equal to 1/100 yrs or 10^{-2} per yr
    - Category 2 event sequences have a frequency less than 10^{-2} per yr and greater than or equal to [(1/10000)/100 yrs] or 10^{-6} per yr
  - Mean frequency will be used to determine if the event sequence is in Category 1 or Category 2
  - If the mean frequency is below 10^{-6} per yr the event sequence is determined to be beyond Category 2
  - To assess margin and completeness in the PSA, a stopping rule is used: event sequences having a frequency greater than 10^{-8} per yr will be considered

Event Sequence Frequency Binning
(Continued)

- **Identifying controls for preventing or mitigating beyond Category 2 event sequences**
  - Event sequences identified below 10^{-6} per yr, but above 10^{-8} per yr will have best estimate frequency and consequences assessments performed
  - Event sequences that have the potential to exceed the Category 2 dose limits will be examined for potential important to safety SSCs

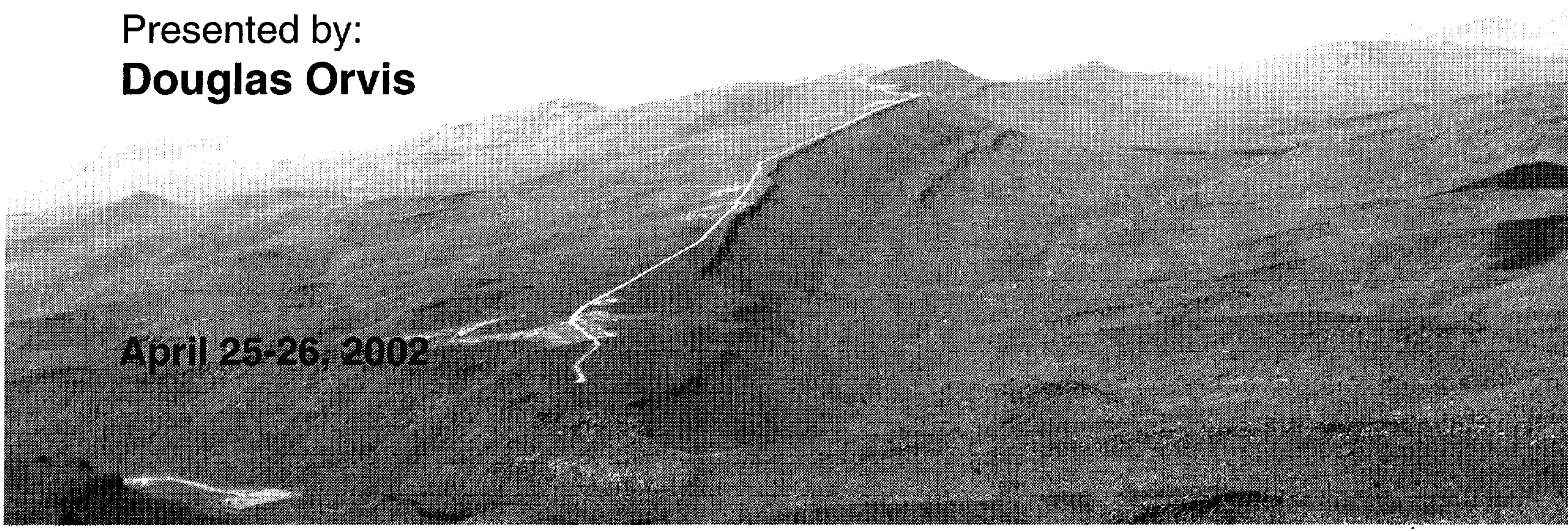
U.S. Department of Energy
Office of Civilian Radioactive Waste Management

YUCCA MOUNTAIN PROJECT

Preclosure Safety Analysis Guide - Uncertainty Analysis

Presented to:
NRC Technical Exchange on Preclosure Safety Analysis Guide

Presented by:
Douglas Orvis



April 25-26, 2002

Uncertainty Analysis

- **Purpose:**
  - **Demonstrate how uncertainty/sensitivity analysis will be applied in Preclosure Safety Analysis**
- **Scope:**
  - **Overview of approach and example application**

YMRP Considerations of Uncertainty

- **Hazards Analysis**
  - ES: "The [PSA] considers ... probabilities ... uncertainties associated with potential hazards."
  - 4.1.1: "... considers ... potential hazards, ... [accounting for] range of uncertainty associated with the data ..."
- **Frequency Analysis**
  - 4.1.1.3.2, RM3: "ensure that uncertainties ...[in] probability estimates are quantified."[AC3]
  - 4.1.1.3.2, RM4: "Ensure that technical bases [for inclusion/exclusion of hazards] include consideration of uncertainties."[AC4]
- **Consequences**
  - 4.1.1.5.1 & .2, RM2: "Verify that ... uncertainty in the input data is appropriately considered ..."

YMRP Considerations of Uncertainty
(Continued)

- **Consequences**
  - **4.1.1.5.1 & .2, RM2: "Verify that ... uncertainty in the input data is appropriately considered ..."**
- **Classification Analysis**
  - **4.1.1.6, RM3: "Ensure the categorization methodology provides due consideration of uncertainties and sensitivity analyses for event sequence frequencies ... consistent with the applicable portions of ...[NRC] policy and guidance"**

PSA Guide: Uncertainty and Sensitivity

- **Section 9. provides methods for identifying, quantifying, propagating, and interpreting uncertainties in frequency and consequence analyses**
  - Uncertainties in models and input information
  - Representing uncertainties in input and output
  - Propagating uncertainties
  - Uncertainty vs sensitivity analysis
  - Importance measures
  - Examples
- **Section 7.5 describes method for characterizing and quantifying uncertainty in input parameters**
- **Section 8 describes uncertainties in consequence analyses**
- **Other sections also address facets of uncertainty analysis, and its application**

Sources of Uncertainty

- **Parameter**
  - **Aleatory/randomness**
  - **Epistemic/knowledge)**
- **Model (epistemic/knowledge)**
- **Completeness (epistemic/knowledge)**

Modeling Uncertainties

- **Generic**
  - Application of accepted modeling such as event/fault trees, exponential failure as representations of reality
  - Not treated
- **MGR Specific**
  - "Mapping" of design into logic models, description of human actions, common-cause failures
  - Reduce through team effort of safety analysts and design; rigorous checking
  - Treat with alternative modeling/sensitivity, as appropriate

Completeness Uncertainties

- Residual or unknown risks that may remain
- Treated by performing exhaustive, structured, and reviewed PSA

Identifying and Treating Parameter Uncertainties

- Randomness in measured/calculated values
- Applicability to MGR operations, conditions and environment
- Amenable to quantification and propagation through frequency or consequence models
- Significance evaluated through sensitivity or importance analyses

Representing Uncertainties in Input and Output Variables

- **Uncertainty on input and calculated outputs will usually imply 90-percent confidence interval**
  - Lower Bound (LB) is 5% confidence limit
  - Upper Bound (UB) is 95% confidence limit
- **Uncertainty in given input described by a Probability Density Function (PDF)**
  - Lognormal distribution is used for most inputs (the "workhorse")
  - Normal distribution used where appropriate
  - Conjugate distributions may be used for computational ease (e.g., beta, gamma)
- **Uncertainty in event sequence frequency (output) generally represented by a lognormal distribution as natural for product of several distributed variables**

Representing Uncertainties in Input Parameters

- **Uncertainties defined for failure on demand (q), or failure rate (λ)**
- **Apply generic databases, where applicable**
- **Apply experience data, where applicable**
- **Classical Approach**
  - **Observed data ("f" failures in "n" tests, or "f" failure in time "T")**
  - **Calculate 5% and 95% confidence limits; e.g., using Chi-Square distribution**
- **Bayesian Approach**
  - **Analyst selects an appropriate prior PDF for parameter with given mean (or median) and 90% uncertainty bounds**
  - **Generic data applied as evidence to produce posterior PDF**
  - **Experience data (if any) treated as "update" to generic parameters**

Parameter Uncertainties from Generic Databases

Comp.	Mode	Failure Rate Mean	Error Factor	No. Fail.	Demand (Hours)
Pump-MD	F. Start	3E-3/d	5	137	48459
Pump-MD	F. Run	3E-5/hr	10	216	(7.5E-6)
Switch-Limit	Spurious Op.	1E-6/hr	10	7	(8E-6)

Identifying and Treating Parameter Uncertainties

- **Classical Estimation: Prob. of Drop/Lift (Hypothetical)**
- **Number of failures observed = 3**
- **Number of trials recorded = 18,000**
- **Point estimate = 3/18000 = 1.67E-4**
- **UB = $X^2(2f+2,0.05)/2n$ = 4.31E-4**
- **LB = $X^2(2f,0.95)/2n$ = 4.54E-5**
- **Median (assumed LN) = $[UB/LB]^{1/2}$ = 1.40E-4**
- **Error Factor = UB/Median = 3**

Propagation of Uncertainties in Event Sequence Frequency Analysis

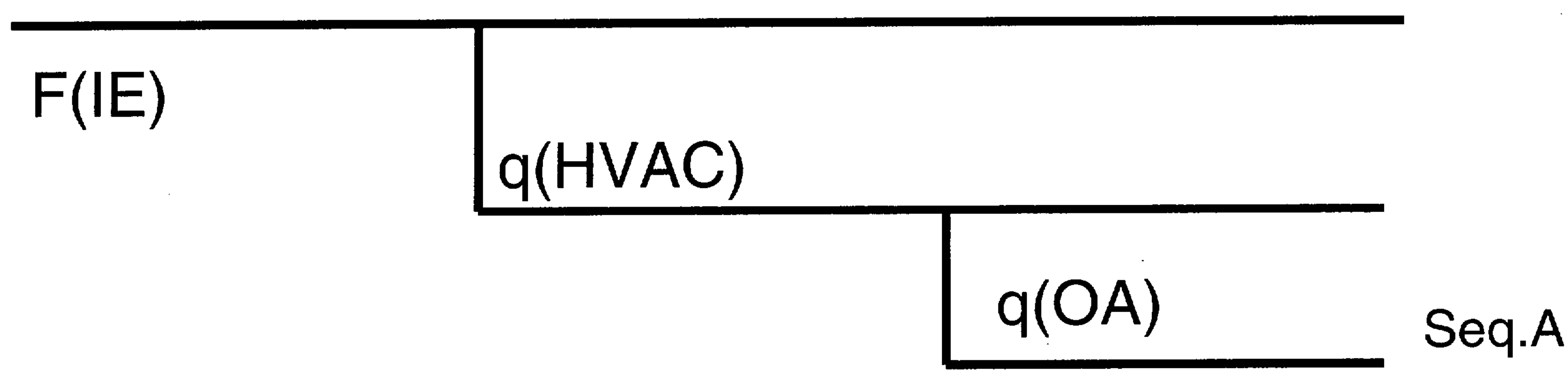
- **Analytic-Direct Integration Approach**
  - Generally not possible for products of more than two or three distributed variables; too complex
- **Moments Methods - approximate, but very useful**
- **Numerical Analysis**
  - Discrete probability distribution (DPD)
  - Monte Carlo (MC)/Latin Hypercube (LHC)
- **Monte Carlo/Latin Hypercube methods are built into SAPHIRE, or @Risk add-in to EXCEL**

Sequence Frequency Analysis Including Uncertainty

- Construct event tree for event sequences including initiating events and event headings (top event)
- Construct fault tree and/or human-reliability models for top events
- Quantify input parameters including uncertainties
- Perform sequence analysis to identify event headings involved and/or minimal cutsets from FT linking
- Quantify frequency of each sequence
  - Point estimate by direct multiplication
  - Uncertainty distribution via direct analysis (approximate); or MC/LHC (e.g., SAPHIRE, or EXCEL with @RISK)

Propagation of Uncertainties in Event Sequence Frequencies

Initiating Event: Drop/Breach Waste	HVAC Auto-Start	Operator Starts Emergency HVAC



$$F(SeqA) = F(IE) * q(HVAC) * q(OA)$$

Propagation of Uncertainties in Event Sequence Frequencies

Event	Median	Unit	EF	Mean	Mean/Med	STD/Mean
F(IE)	1E-1	yr^{-1}	3	1.25E-1	1.25	0.75
q(HVAC)	1E-3	dmd^{-1}	3	1.25E-3	1.25	0.75
q(OA)	1E-2	dmd^{-1}	5	1.62E-2	1.62	1.27
F(SeqA)	1E-6	yr^{-1}	9.4	2.54E-6	2.54	2.33

F(IE), q(HVAC), q(OA) and F(Seq A) are lognormal.

Application of Mean to Categorize Event Sequence Frequencies

EF	Mean/ Median	Mean/UB	UB/Mean
2	1.09	0.55	1.83
3	1.25	0.42	2.40
5	1.61	0.32	3.10
10	2.66	0.27	3.75

Sensitivity Analysis

- Some uncertainties cannot be represented by PDF
- Sensitivity analysis gives insights on their risk significance
- Modeling uncertainties where sensitivities may be applied
  - Effect of alternative system configurations (e.g., added redundancy)
  - Effect of operator actions/recovery
  - Effect of adding alarms and logic model for operator response
  - Parameter uncertainty scoping analysis where probability of basic event charged to bounding valve, 0 or 1.0, to determine change in output

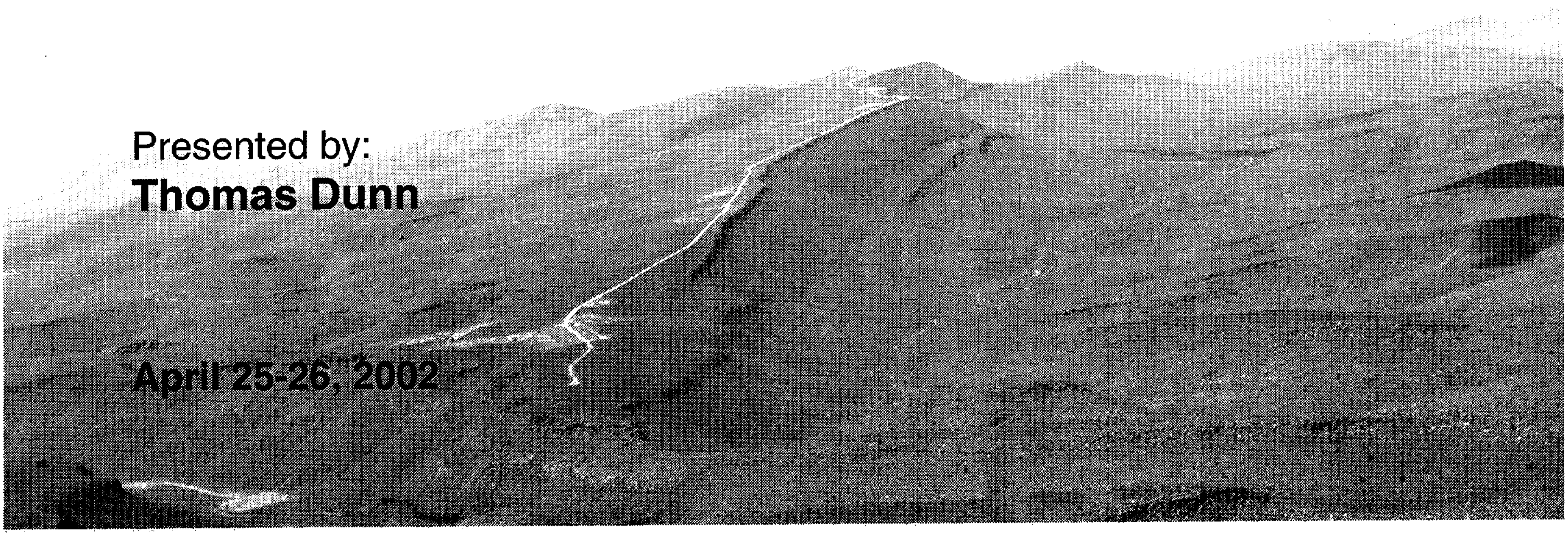
U.S. Department of Energy
Office of Civilian Radioactive Waste Management

YUCCA MOUNTAIN PROJECT

Preclosure Safety Analysis Guide - Consequence Analysis

Presented to:

NRC Technical Exchange on Preclosure Safety Analysis Guide



Presented by:

Thomas Dunn

April 25-26, 2002

Consequence Analysis

- **Purpose of Section 8 Consequence Analysis:**
  - **Methodology for calculating offsite doses for Category 1 and Category 2 event sequences is described**
  - **Definitions and sources of data for key dose measures are defined**
    - **Total Effective Dose Equivalent (TEDE)**
    - **Highest of the Committed Dose Equivalents (CDEs) plus the Deep-Dose Equivalent**
    - **Lens of the Eye**
    - **Skin and Extremities**

Example Source Terms Discussed

- **Commercial Spent Nuclear Fuel (CSNF) and Crud**
  - Reference and basis for average and maximum PWR and BWR source terms discussed
  - Category 1 event sequences involving CSNF
    - Average PWR fuel used for all event sequences since it bounds average BWR fuel
  - Category 2 event sequences involving CSNF
    - Average and maximum BWR and PWR source terms to be used
  - Example average and maximum radionuclide inventories per fuel assembly described
  - Crud activity (corrosion product on surface of fuel assembly) described and example crud source term calculation presented

Other Source Terms

- **Source Terms for U.S. Department of Energy Spent Nuclear Fuel**
  - Reference provided for isotopic compositions for over 250 fuel types discussed
  - Discussion of National Spent Nuclear Fuel Program's development of average and bounding source terms for these fuels presented
- **Source Terms for Vitrified High-Level Radioactive Waste**
  - Example isotopic concentrations for HLW presented with references

Other Source Terms

- **Plutonium Disposition Waste Form**
  - **Guide does not provide references to immobilized plutonium source term since this DOE program is currently on-hold**
  - **MOX fuel not discussed in the Guide but will be in future revisions as needed**
    - **Source terms for MOX fuel are discussed in *Design Basis Event Frequency and Dose Calculation for Site Recommendation***
- **Navy spent fuel not discussed in the Guide but will be in future revisions as needed**
    - **Source terms for Navy fuel discussed in *DOE SNF DBE* Offsite Dose Calculations**

Category 1 Offsite Dose

- **Compliance to Category 1 event sequence dose criteria from 10 CFR 63 will be shown using each of the following methods**
  - Normal operating annual doses plus the annual dose from Category 1 event sequences
    - Chronic doses -- average source terms weighted by frequency, release rates and annual average χ/Q's
  - Individual Category 1 event sequences
    - Acute doses-- average source terms, release rates and 0 to 2 hr χ/Q's
  - Combinations of individual Category 1 event sequences that can occur in a single year with a frequency above 10^{-2} per year
    - Chronic doses -- average sources terms, release rates and annual average χ/Q's

Category 2 Offsite Doses

- **Compliance to Category 2 event sequence dose criteria from 10 CFR 63 will be shown using following method**
  - **For each individual Category 2 event sequence, mean and upper bound doses will be estimated**
  - **In general, estimates of the mean doses will be compared to the 10 CFR 63 criteria to show compliance**
    - **Guide describes 3 approaches for estimating uncertainties: stacking conservatisms, using a Monte Carlo sampling technique within the GENII-S computer program, or using an EXCEL spreadsheet with @RISK**

Dose Pathways

- **Category 1**
  - **Offsite doses (site withdrawal boundary)**
    - **Inhalation**
    - **Ingestion**
    - **Submersion**
    - **Groundshine**
  - **Guide discusses non-involved worker dose**
    - **Chronic exposure over a year**
    - **Distance of 100 m**
- **Category 2**
  - **Offsite doses (site withdrawal boundary)**
    - **Inhalation**
    - **Submersion**
    - **Groundshine**

Release Fractions

- **Commercial SNF**
  - **Release fractions resulting from cladding failure due to a drop of intact CSNF presented**
    - **Basis is developed in *Commercial SNF Accident Release Fractions***
    - **Releases are different if drop occurs in pool (only noble gases released) as compared to in air (gases and particulates released)**
  - ***Commercial SNF Accident Release Fractions* is now under revision to include a better representation of crud releases, particulate releases and release fractions for non-intact CSNF**

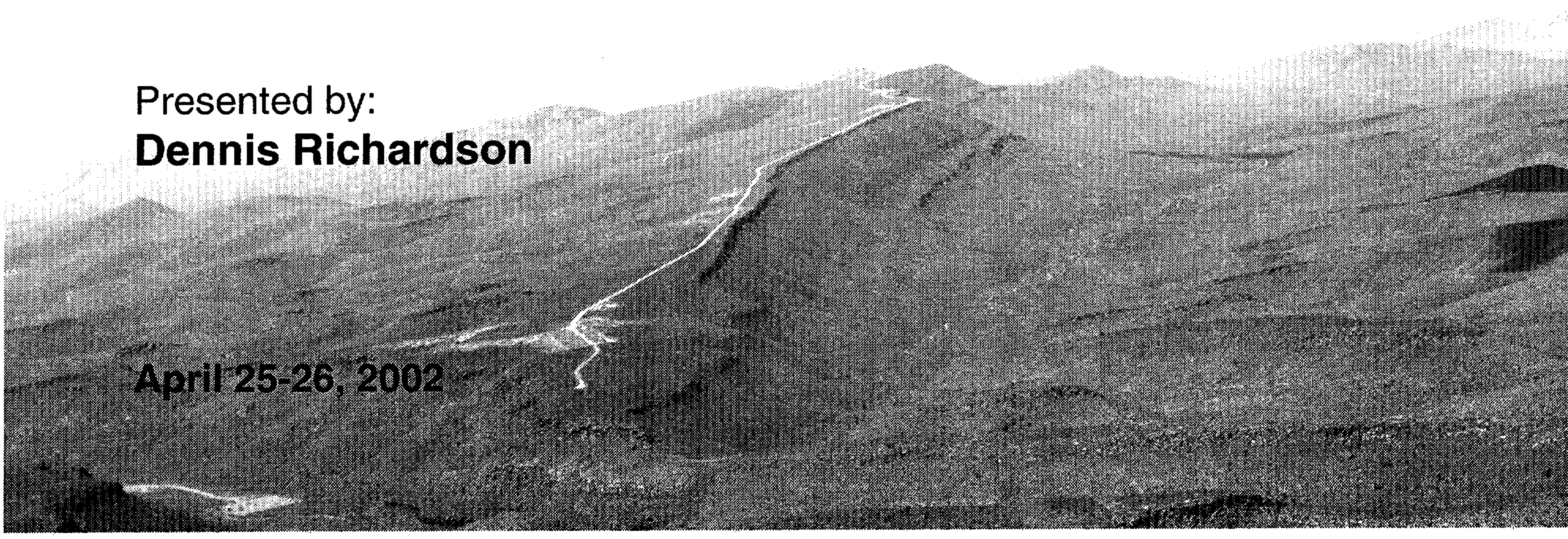
U.S. Department of Energy
Office of Civilian Radioactive Waste Management

YUCCA MOUNTAIN PROJECT

Preclosure Safety Analysis Guide - 10 CFR 63.2 Design Basis

Presented to:

NRC Technical Exchange on Preclosure Safety Analysis Guide



Presented by:

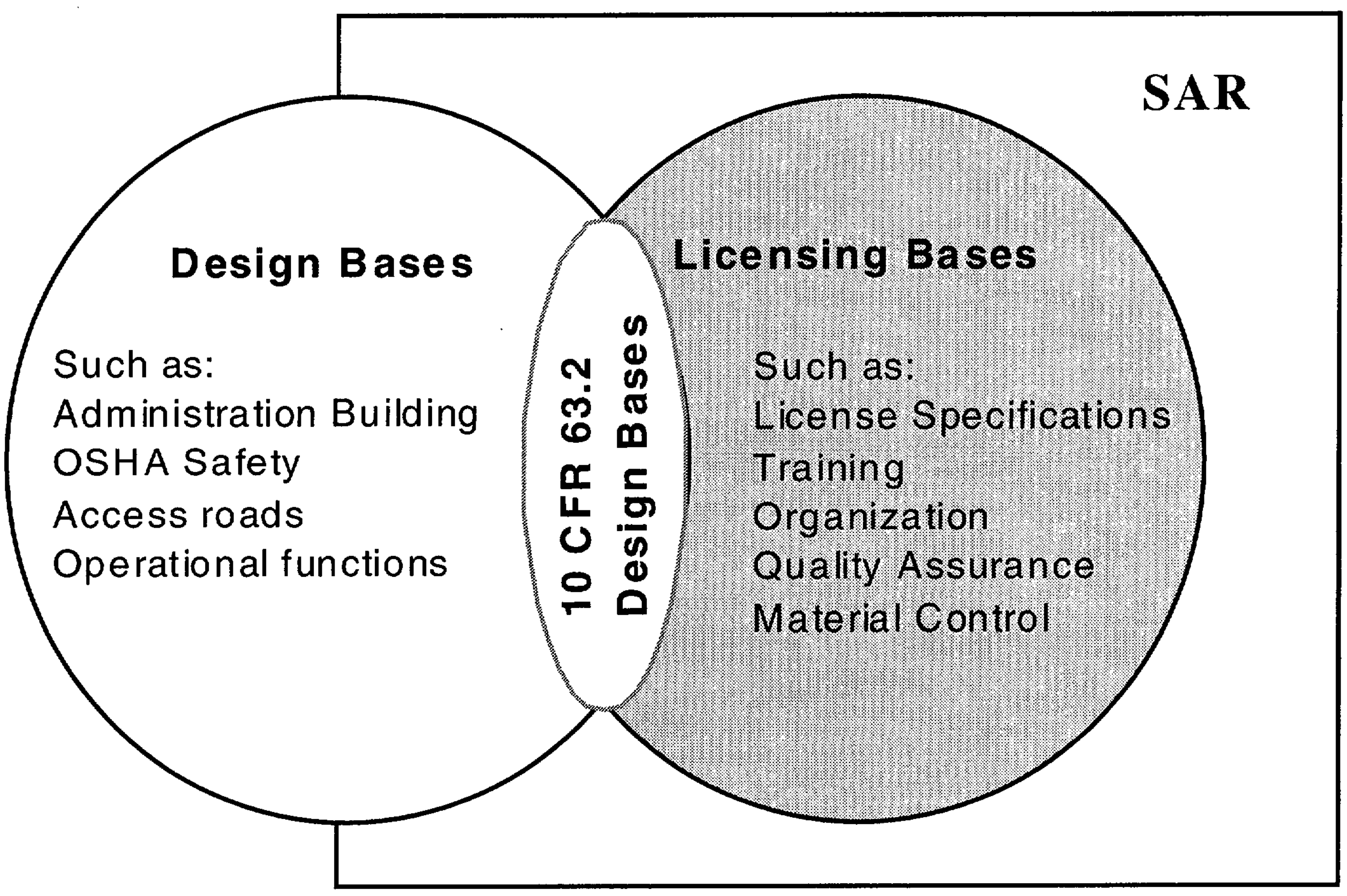
Dennis Richardson

April 25-26, 2002

Identifying 10 CFR 63.2 Design Bases

- **10 CFR 63.2 Definitions**
  - **Design bases means that information that identifies the specific functions to be performed by a structure, system, or component of a facility and the specific values or ranges of values chosen for controlling parameters as reference bounds for design**
  - **The values for controlling parameters for external events include:**
    - **Estimates of severe natural events to be used for deriving design bases that will be based on consideration of historical data on the associated parameters, physical data, or analysis of upper limits of the physical processes involved; and**
    - **Estimates of severe external human-induced events to be used for deriving design bases, that will be based on analysis of human activity in the region, taking into account the site characteristics and the risks associated with the event**

Relationship of 10 CFR 63.2 Design Basis and the Safety Analysis Report



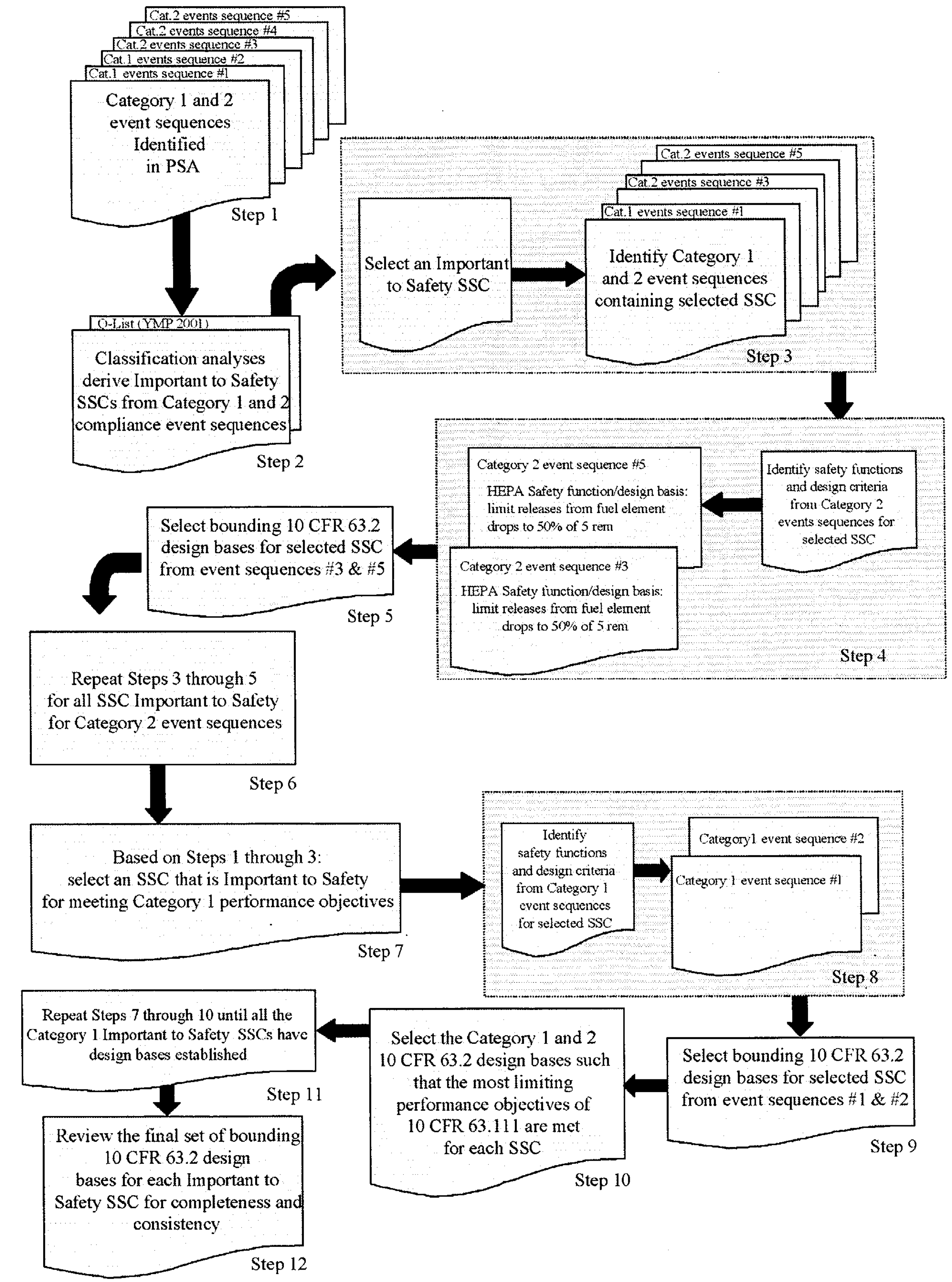
Guidance

- **Preclosure design basis requirements are developed from the geologic repository Category 1 and 2 event sequences identified from preclosure safety analysis**
- **Category 1 and 2 event sequences are evaluated against their performance objectives**
  - **SSC important to safety functions are identified from these event sequences**
  - **SSCs in the event sequences required to meet preclosure performance objectives are selected as important to safety**

Guidance
(Continued)

- Design basis are established to describe the SSC important to safety function, and design criteria are established for each important to safety function
  - Design criteria are bounding values for controlling specific values or ranges of values chosen for controlling parameters as reference bounds for the design

- **Design features that maintain event sequences Beyond Category 2 will be candidates for designation as important to safety**


Cat.2 events sequence #5
Cat.2 events sequence #4
Cat.2 events sequence #3
Cat.1 events sequence #2
Cat.1 events sequence #1
Category 1 and 2 event sequences Identified in PSA
Step 1
Q-List (YMP 2001)
Classification analyses derive Important to Safety SSCs from Category 1 and 2 compliance event sequences
Step 2
Select an Important to Safety SSC
Cat.2 events sequence #5
Cat.2 events sequence #3
Cat.1 events sequence #1
Identify Category 1 and 2 event sequences containing selected SSC
Step 3
Identify safety functions and design criteria from Category 2 events sequences for selected SSC
Category 2 event sequence #5
HEPA Safety function/design basis: limit releases from fuel element drops to 50% of 5 rem
Category 2 event sequence #3
HEPA Safety function/design basis: limit releases from fuel element drops to 50% of 5 rem
Step 4
Select bounding 10 CFR 63.2 design bases for selected SSC from event sequences #3 & #5
Step 5
Repeat Steps 3 through 5 for all SSC Important to Safety for Category 2 event sequences
Step 6
Based on Steps 1 through 3: select an SSC that is Important to Safety for meeting Category 1 performance objectives
Step 7
Identify safety functions and design criteria from Category 1 event sequences for selected SSC
Category1 event sequence #2
Category 1 event sequence #1
Step 8
Select bounding 10 CFR 63.2 design bases for selected SSC from event sequences #1 & #2
Step 9
Select the Category 1 and 2 10 CFR 63.2 design bases such that the most limiting performance objectives of 10 CFR 63.111 are met for each SSC
Step 10
Repeat Steps 7 through 10 until all the Category 1 Important to Safety SSCs have design bases established
Step 11
Review the final set of bounding 10 CFR 63.2 design bases for each Important to Safety SSC for completeness and consistency
Step 12

Examples of MGR Design Bases and Supporting Design Information-1

- **Functional Design Bases (Derived from 10 CFR 63.2)**
  - HVAC for surface facility shall ensure that aggregate offsite dose for Category 1 event sequences is in accordance with 10CFR63.111(a)
  - HVAC system shall ensure that important to safety functions will be available for sufficient time and sufficient capacity, assuming the occurrence of Category 1 event sequences
- **Controlling Parameters Design Bases**
  - HVAC shall be equipped with HEPA filtration that removes SNF particulate matter of greater than X microns with an efficiency of Y

Examples of MGR Design Bases and Supporting Design Information-1
(Continued)

- HVAC shall remain operational with a) full filtration efficiency, and b) maintain a negative pressure differential between the external environment and SNF handling areas for X hours with probability Y, following the occurrence of the bounding Category 1 event sequence

- **Supporting Design Information**
  - Description of HVAC layout; air exchange rates; volumetric airflow rate; diameter of ducts, etc.
  - Description of overall design including fact that there are separate HVACs for three zones that maintain negative pressure differentials between the zones and between the outer zone and the environment

Examples of MGR Design Bases and Supporting Design Information -1

(Continued)

- Description of redundancy in fans and electrical power supplies, control system, etc.
- Description of operational controls that will halt operations if the HVAC is inoperable
- System reliability analysis that verifies that HVAC will remain operational for X hours with a probability of Y

Examples of MGR Design Bases and Supporting Design Information-2

- **Functional Design Bases (Derived from 10 CFR 63.2)**
  - Disposal container (sealed waste package) shall withstand, without breaching, all credible impacts from normal handling, Category 1 and Category 2 event sequences
- **Controlling Parameters Design Bases**
- **An exhaustive list of design bases is developed based on expected MGR operations and event sequence analyses, resulting in controlling design criteria, such as:**
  - Vertical end-on drop height of x meters
  - Horizontal side-on drop height of y meters

Examples of MGR Design Bases and Supporting Design Information-2
(Continued)

- Corner drop height of x meters
- Slap-down
- Vibratory ground motion for Frequency Category 2 Design Earthquake
- Maximum rock mass of R tonnes falling r meters etc.

- **Supporting Design Information**
  - Description of waste package handling operations that demonstrates that lift heights are less than allowed by the controlling design basis (criteria); provides defense in depth

Examples of MGR Design Bases and Supporting Design Information-2
(Continued)

- Description of hold-down fixtures that prevent slapdown in normal operations and seismic events
- Description of emplacement drift rock quality, ground support systems, etc., that demonstrates that probability of rock of R tonnes is not credible (beyond Category 2)

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

YUCCA MOUNTAIN PROJECT

Preclosure Safety Analysis Guide - Classification Process

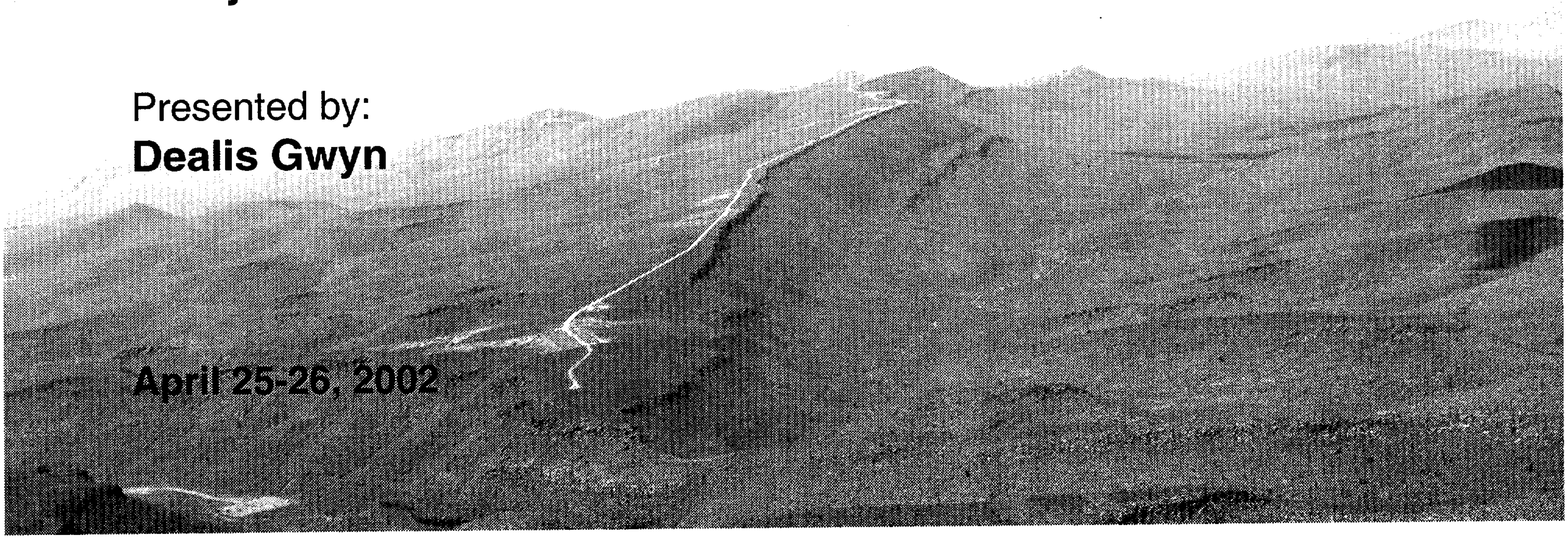
Presented to:

NRC Technical Exchange on Preclosure Safety Analysis Guide

Presented by:

Dealis Gwyn

April 25-26, 2002



Agenda

- Overview
- Preclosure Safety Analysis Process
- Summary

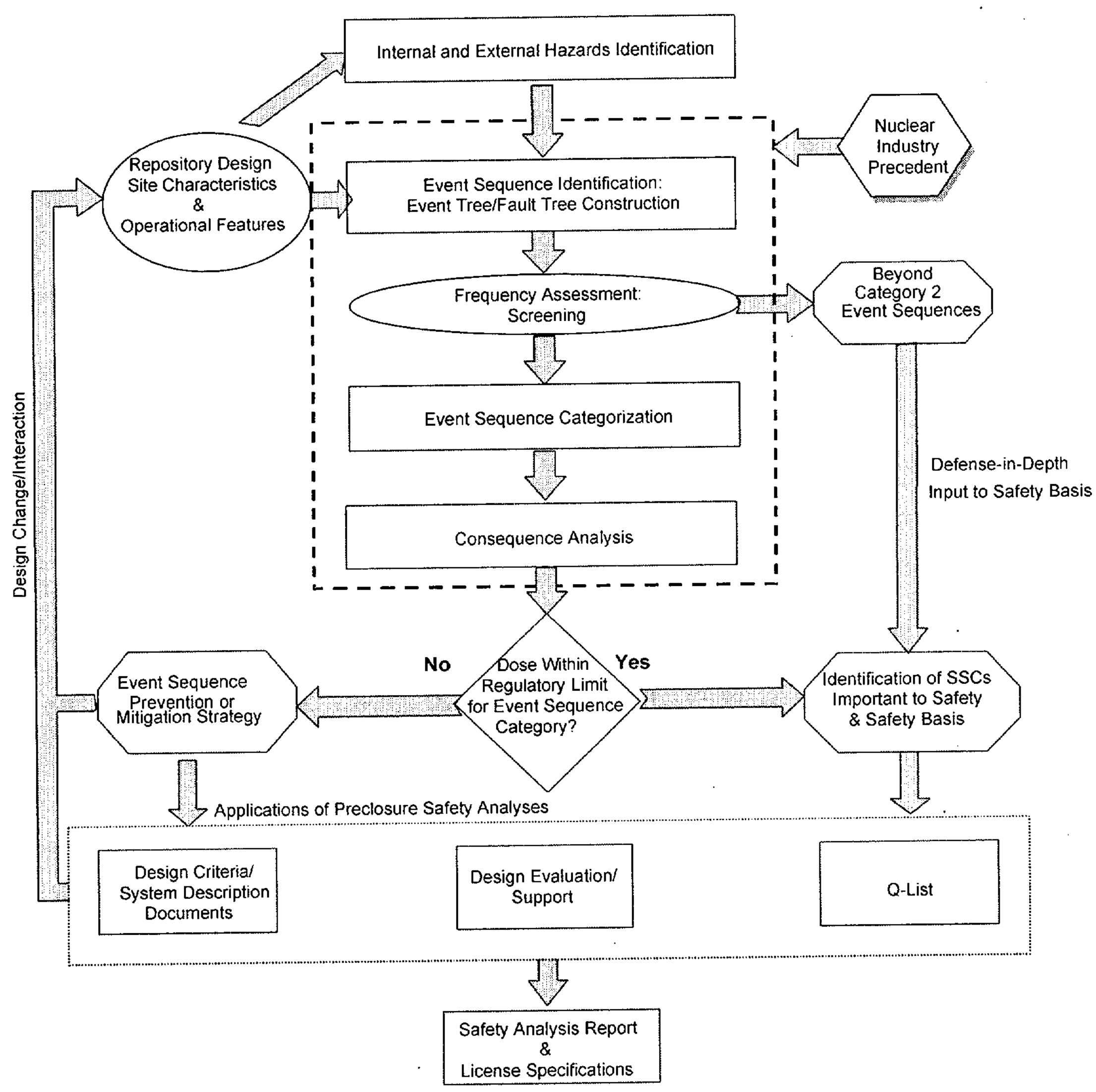
Objective

- **Objective**
  - **Discuss classification process**
    - **Background**
    - **Preclosure Safety Analysis**
    - **Important to safety criteria**
    - **Procedure AP-2.22Q**
    - **Q-List**

Background

- **10 CFR 63.2**
  - **Important to safety definition**
  - **Category 1 event sequence definition**
  - **Category 2 event sequence**

PSA Process: Classification



Classification Procedure

- AP-2.22Q, ***Classification Criteria and Maintenance of the Monitored Geologic Repository Q-List***
  - Combines QAP-2-3, *Classification of Permanent Items and YAP-2.7Q, Item Classification and Maintenance of the Q-List*
  - Identifies SSCs that are important to safety and waste isolation based on 10 CFR 63.2 definitions
  - Risk-informed, performance based
  - Item identified as important to safety must be linked to at least one Category 1 or Category 2 event sequence

Important to Safety Classification Criteria

- **Quality Level 1**
  - **Category 1 event sequence**
    - **Frequency – Those event sequences that are expected to occur one or more times before permanent closure of the geologic repository**
    - **Consequence – Consequence potential of greater than 100 mrem TEDE when considering the frequency weight sum of category 1 event sequences, contributions from normal operations, and any category 1 combinations of event sequences**

Important to Safety Classification Criteria
(Continued)

- **Quality Level 1**
  - Category 2 event sequence
    - Frequency – Other event sequences that have at least one chance in 10,000 of occurring before permanent closure
    - Consequence – Consequence potential of greater than 5 rem TEDE, or the sum of the deep dose equivalent and the committed dose to any individual organ or tissue (other than the lens of the eye) of 50 rem, or lens dose equivalent of 15 rem, or the shallow dose equivalent to the skin of 50 rem

Important to Safety Classification Criteria
(Continued)

- **Quality Level 2**
  - Category 1 event sequence
    - Frequency – Those event sequences that are expected to occur one or more times before permanent closure of the geologic repository
    - Consequence – Consequence potential of greater than 15 mrem TEDE when considering the frequency weight sum of category 1 event sequences, contributions from normal operations, and any category 1 combinations of event sequences

Important to Safety Classification Criteria
(Continued)

- **Quality Level 2**
  - Category 2 event sequence
    - Frequency – Other event sequences that have at least one chance in 10,000 of occurring before permanent closure
    - Consequence – Consequence potential of greater than 100 mrem TEDE, the sum of the deep dose equivalent and the committed dose to any individual organ or tissue (other than the lens of the eye) of 1000 mrem, lens dose equivalent of 300m rem, or the shallow dose equivalent to the skin of 1000 mrem

Important to Safety Classification Criteria
(Continued)

- **Quality Level 3**
  - Category 1 event sequence
    - Frequency – Those event sequences that are expected to occur one or more times before permanent closure of the geologic repository
    - Consequence – Consequence potential of greater than 0.15 mrem TEDE when considering the frequency weight sum of category 1 event sequences, contributions from normal operations, and any category 1 combinations of event sequences or worker dose greater than 5 rem

Important to Safety Classification Criteria (Continued)

- **Quality Level 3**
  - **Category 2 event sequence**
    - **Frequency – Other event sequences that have at least one chance in 10,000 of occurring before permanent closure**
    - **Consequence – Consequence potential of greater than 15 mrem TEDE, the sum of the deep dose equivalent and the committed dose to any individual organ or tissue (other than the lens of the eye) of 150 mrem, lens dose equivalent of 45 mrem, or the shallow dose equivalent to the skin of 150 mrem**

Important to Safety Classification Steps

- **Classification of SSCs in category 1 event sequences**
  - Calculate normal operating dose from surface and subsurface normal releases
  - Calculate Category 1 event sequence dose
  - Calculate aggregate Category 1 dose
  - Identify event sequences that include the SSC being classified
  - Perform functional failure analysis for each event sequence that includes SSC being classified
  - Perform functional failure analysis for each Category 1 combination of event sequences that include SSC being classified
  - Classify SSC based on highest classification level resulting from functional failure analysis

Important to Safety Classification Steps

- **Classification of SSCs in category 2 event sequences**
  - Calculate Category 2 event sequence dose
  - Identify event sequences that include the SSC being classified
  - Perform functional failure analysis for each event sequence that includes SSC being classified
  - Classify SSC based on highest classification level resulting from functional failure analysis

Example - Waste Package Transporter Failure

	WP Transporter Failure on North Ramp	Probability of Waste Package Failure	Probability of CSNF Cladding Failure	Event Sequence Frequency	Event Sequence Category	Consequences	Transporter Classification
Example 1	1E-07/yr	1.0	1.0	1E-07/yr	Beyond Category 2	> 5 rem	QL-1*
Example 2	1E-07/yr	1.0	1.0	1E-07/yr	Beyond Category 2	0 rem	CQ
Example 3	1E-10/yr	1.0	1.0	1E-10/yr	Beyond Category 2	Not Calculated	CQ

*Feature(s) of transporter that prevent failure

Examples - CSNF Basket Lifting Device Failure

	CSNF Basket Lifting Device Failure within WHB Confinement	*Probability CSNF Cladding Fails*	*Probability HEPA Filters for Required Time*	*Event Sequence Frequency*	*Event Sequence Category*	*Consequences with HEPA*	*Consequences without HEPA*	*HEPA Classifi-cation*
Example 1	1E-01/yr	1.0	1.0	1E-01/yr	Category 1	ES - 5 mrem NO - .2 mrem <u>AS – 3 mrem</u> 8.2 mrem	ES- 20 mrem NO - .2 mrem <u>AS – 3 mrem</u> 23.2 mrem	QL-2
Example 2	1E-02/yr	1.0	1.0	1E-01/yr	Category 1	ES - 5 mrem NO - .2 mrem <u>AS – 3 mrem</u> 8.2 mrem	ES- 100 mrem NO - .2 mrem <u>AS – 3 mrem</u> 103.2 mrem	QL-1
Example 3	1E-02/yr	1.0	1.0	1E-01/yr	Category 1	ES - 5 mrem NO - .2 mrem <u>AS – 3 mrem</u> 8.2 mrem	ES- 8 mrem NO - .2 mrem <u>AS – 3 mrem</u> 11.2 mrem	QL-3

Examples - Fire Mitigation

	Fire initiation frequency	*Probability fire will burn 1 hour (time calculated to reach x temperature)*	*Probability fire results in radiological release*	*Event Sequence Frequency*	*Event Sequence Category*	*Consequences with fire mitigation*	*Impact of fire mitigation unavailable at start of fire*	*Fire Mitigation Classification*
Example 1	1E-05/yr	1E-03/yr	1E-04/yr	1E-12/yr	Beyond Category 2	Not calculated	Not calculated	CQ
Example 2	1E-02/yr	1E-01/yr	1E-02/yr	1E-05/yr	Category 2	2 rem	6 rem	QL-1
Example 3	1E-02/yr	1E-01/yr	1E-02/yr	1E-05/yr	Category 2	2 rem	4 rem	QL-2

Q-List

- **Maintained consistent with classification analyses**
  - **Application of AP-2.22Q**
  - **Consistent with evolving design**

Example Q-List

System	*Subsystem*	*Item Identifier**	*Item Description**	*QL**	*Principal Design Code*
Structures/Buildings (CS)	Waste Handling Building (CSH)				
		CSH-ST-0001	Waste Handling Building Outer Walls	QL-1	ACI-xx-yyyy
		CSH-ST-0002, etc.	Other Waste Handling Walls	CQ	ACI-rr-ssss
	Waste Treatment Building (CST)				
		CST-ST-0001	Waste Treatment Building Radwaste Containment Walls	QL-2	Reg Guide 1.143
		CST-ST-0002, etc.	Other Waste Treatment Building Walls	CQ	ACI-rr-ssss
Site Generated Radiological Waste (MR)	Fuel Pool Cooling and Cleanup (MRP)	MRP-PU-0001	Fuel Pool Cooling Pump A	QL-2	ASME---
		MRP-PIP-0001	Fuel Pool Cooling Pump A Suction Pipe	QL-2	ANSI-B31.1
		MRP-FIL-0001	Fuel Pool Filter A	QL-2	ANSI-x.xxxx

***Required field per AP-2.22Q**

Path Forward

- **Preclosure Safety Analysis Guide**
  - Classification of SSCs related to criticality event sequences
  - Classification of SSCs related to radiological worker safety for Category 1 event sequences
  - Q-List format and maintenance

Summary

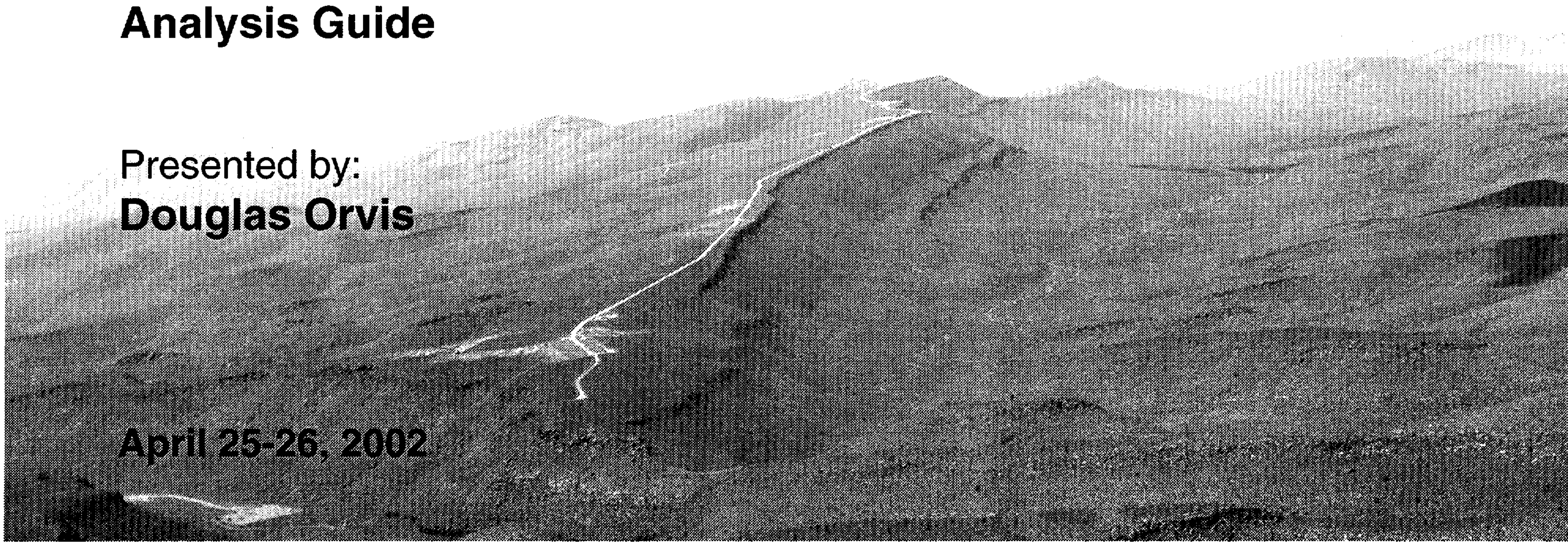
- **Risk-informed classification process**
  - Classifications linked to preclosure safety analysis
  - Minimum of one Category 1 or 2 event sequences
- **Guide updates**
  - Criticality classification
  - Radiological worker safety
  - Q-List maintenance

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

YUCCA MOUNTAIN PROJECT

Preclosure Safety Analysis Guide - Comparison to Draft YMRP

Presented to:
NRC Technical Exchange on Preclosure Safety Analysis Guide



Presented by:
Douglas Orvis

April 25-26, 2002

Preliminary Review of Draft YMRP

- **Compared PSA Guide approaches with corresponding sections in Draft YMRP**
  - **Areas of review**
  - **Review methods**
  - **Acceptance criteria**

Preliminary Review of Draft YMRP
(Continued)

- Intent of PSA Guide and Draft YMRP is risk-informed, performance based philosophy
- PSA Guide appears consistent with corresponding sections of Draft YMRP
- Detailed review in progress

Future Revisions to PSA Guide

- Linked to Draft YMRP, as appropriate
- Develop details and/or new methods sections for areas not completed in initial version; e.g.,
  - Internal-event fires
  - Internal-event floods
  - Vulnerabilities to software unreliability
  - Work interfaces and responsibilities

Future Revisions to PSA Guide

(Continued)

- **Develop details and/or new methods sections for areas not completed in initial draft; e.g.,**
  - Licensing specifications
  - Emergency Operating Procedures
  - 10 CFR 63.44 evaluations
  - Interfaces and integration of other analysis/design activities required by 10 CFR 63.112 and draft YMRP not directly associated with performing hazards and event-sequence analyses
- **Refine approach for evaluating vulnerabilities to software unreliability**

Conclusion

- Preliminary review concludes methods presented in Preclosure Safety Analysis Guide appear consistent with corresponding sections of Draft YMRP, Rev.2
- Detailed comparison ongoing
- Future updates planned for PSA Guide